0 1987

REC-ERC-87-11

HABITAT MANAGEMEMT MODELS FOR SELECTED WILDLIFE MANAGEMENT PRACTICES IN THE NORTHERN GREAT PLAINS

June 1987

Engineering and Research Center

U. S. Department of the Interior

Bureau of Reclamation

OR L

COMPLETED

MS-230 (1-76)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.
REC-ERC 87-11

[redacted]

3. RECIPIENT'S CATALOG NO.

4. TITLE AND SUBTITLE
Habitat management models for selected wildlife management practices in the Northern Great Plains

5. REPORT DATE
June 1987

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Patrick J. Sousa

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Bureau of Reclamation
Office of Environmental Technical Services
Engineering and Research Center
Denver, CO 80225

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
DIBR

15. SUPPLEMENTARY NOTES

Ed:mjc

16. ABSTRACT

This report describes the effects of selected management actions in the Northern Great Plains on habitat for the gadwall, blue-winged teal, sharp-tailed grouse, Baird's sparrow, gray partridge, and muskrat. Categories of management actions discussed in this manuscript include Land Acquisition (fee title, easement), Upland Vegetation Development (plant dense nesting cover, plant native grasses, woodland development), Upland Vegetation Maintenance/Management (prescribed burning), Upland Vegetation Protection (grazing control), Wetland Development (construct seasonal wetlands, construct semipermanent wetlands, restore drained wetlands), and Island Construction (nesting islands). Information provided for each action includes the purpose, effects of the action, maintenance and management, labor and materials, and a model describing the functional relationships between the action and selected habitat variables.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- Wildlife management
Management actions
Management costs

b. IDENTIFIERS-- wetland construction/wetland restoration/island construction/fee title/easement/plant dense nesting cover/plant native grasses/woodland development/prescribed burning/grazing control

c. COSATI Field/Group *COWRR:*

18. DISTRIBUTION STATEMENT
Available from the National Technical Information Service, Operations Division, Springfield, Virginia 22151.
Release unlimited

19. SECURITY CLASS (THIS REPORT)
UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE)
UNCLASSIFIED

21. NO. OF PAGES

22. PRICE

HABITAT MANAGEMENT MODELS FOR SELECTED WILDLIFE MANAGEMENT PRACTICES IN THE NORTHERN GREAT PLAINS

by

Patrick J. Sousa
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

Under Interagency Agreement
with
Office of Environmental Technical Services
U.S. Bureau of Reclamation
P.O. Box 25007
Denver Federal Center
Denver, CO 80225

ACKNOWLEDGMENTS

Funding for the development of the management action models contained in this manuscript was provided by the U.S. Bureau of Reclamation, Denver, Colorado, through their Program Related Engineering and Scientific Studies, No. OETS-1 (Office of Environmental Technical Services). The principal individuals responsible for this support, Jay Hokenstrom and George Wallen, deserve much of the credit, because without their support and generous patience this paper would not have been completed.

Much of the work in compiling the initial descriptive and cost information on management activities was performed by Rodney Olson and Chuck Solomon, U.S. Fish and Wildlife Service, Fort Collins, Colorado. Word processing was provided by Carolyn Gulzow, Dora Ibarra, Elizabeth Barstow, and Patricia Gillis.

BLANK PAGE

CONTENTS

Page

ACKNOWLEDGMENTS iii
FIGURES vi
TABLES viii

INTRODUCTION 1.1 1
LAND ACQUISITION 2.1 11
  Fee title 2.1 11
  Easement 2.25 35
UPLAND VEGETATION DEVELOPMENT 3.1 54
  Plant dense nesting cover 3.1 54
  Plant native grasses 3.13 66
  Woodland development 3.25 78
UPLAND VEGETATION MAINTENANCE/MANAGEMENT 4.1 91
  Prescribed burning 4.1 91
UPLAND VEGETATION PROTECTION 5.1 120
  Grazing control (fencing) 5.1 120
WETLAND DEVELOPMENT 6.1 140
  Construct seasonal wetlands 6.1 140
  Construct semipermanent wetlands 6.1 140
  Restore drained wetlands 6.17 156
ISLAND CONSTRUCTION 7.1 168
  Nesting islands (waterfowl) 7.1 168

FIGURES

Number		Page	
1.1	The relationships between habitat variables, derived variables, life requisites, and an HSI for the gadwall and blue-winged teal	1.3	3
1.2	Relationships of habitat variables, cover types, and life requisites in the sharp-tailed grouse HSI model	1.4	4
1.3	Relationships of habitat variables, cover types, and life requisites in the Baird's sparrow HSI model	1.4	4
1.4	Relationships of habitat variables, cover types, and life requisites in the gray partridge HSI model	1.5	5
1.5	Relationships of habitat variables, cover types, and life requisites in the muskrat HSI model	1.6	6
2.1	Conceptual comparison of the number of wetlands of class i available over time with (curve a) and without (curve b) purchase	2.6	16
2.2	Conceptual comparison of change in cover type area over time with and without land purchase	2.13	23
3.1	Examples of how the distribution of planted dense nesting cover changes the ratio of planted cover area to number of idle grid cells	3.9	62
3.2	Examples of how the distribution of planted native grasses changes the ratio of planted cover area to number of idle grid cells	3.21	74
3.3	Examples of how the area and width of planted woodland changes the ratio of planted cover area to number of idle grid cells	3.33	86
4.1	An assumed response of the visual obstruction measurement to burning over one burning cycle	4.10	100
4.2	An assumed relationship between burning and the average annual change in the visual obstruction measurement	4.13	103

Figures (Concluded)

Number Page

4.3 An assumed response of herbaceous canopy cover to burning over one burning cycle 4.15 105

4.4 An assumed relationship between burning and the average annual change in herbaceous cover 4.17 107

4.5 An assumed response of the proportion of herbaceous canopy cover that is grass to burning over one burning cycle 4.19 109

4.6 An assumed relationship between burning and the proportional change in the proportion of the herbaceous canopy cover that is grass 4.21 111

4.7 An assumed response of the maximum height of the grass canopy to burning over one burning cycle 4.22 112

4.8 An assumed relationship between burning and the proportional change in the maximum height of the grass canopy 4.24 114

5.1 Example of how the distribution of grazing exclusion changes the ratio of protected area to number of idle grid cells 5.10 129

5.2 Example of a change in the number of grid cells/2.59 km² due to grazing exclusion on a large-scale basis 5.10 129

5.3 Assumed relationship between grazing intensity and the average visual obstruction measurement 5.12 131

5.4 Assumed relationship between grazing intensity and percent canopy cover 5.14 133

5.5 Assumed relationship between grazing intensity and proportion of the herbaceous canopy cover that is grass 5.14 133

5.6 Assumed relationship between grazing intensity and the maximum height of the grass canopy 5.16 135

6.1 Two potential functions defining the relationship between baseline and maximum estimates of distance from a given cover type providing waterfowl nesting habitat to a wetland ≥0.4 ha 6.14 153

TABLES

Number Page

1.1 Matrix of relationships between selected management actions and habitat variables 1.7 7

1.2 Cover type classification used in the management action models . 1.9 9

2.1 Estimated cost by selected surface cover types for land acquisition through fee title purchase in North Dakota 2.3 13

2.2 Habitat variables potentially affected by fee title purchase of land 2.4 14

2.3 A summary of the habitat variables potentially affected by fee title purchase of land 2.23 33

2.4 Habitat variables potentially affected by wetland easements 2.27 37

2.5 A summary of the habitat variables potentially affected by wetland easements 2.42 52

3.1 Cost categories and estimated costs for planting introduced grass-legume cover in the Dakota pothole region 3.3 56

3.2 Cost categories and estimated costs for planting dense nesting cover in North Dakota 3.4 57

3.3 Habitat variables potentially affected by planting dense nesting cover 3.6 59

3.4 A summary of the habitat variables potentially affected by planting dense nesting cover 3.11 64

3.5 Cost categories and estimated costs for planting warm-season native grasses in the Dakota pothole region 3.15 68

3.6 Cost categories and estimated costs for planting native grasses in North Dakota 3.16 69

3.7 Habitat variables potentially affected by planting native grasses 3.18 71

Tables (Continued)

Number Page

3.8 A summary of the habitat variables potentially affected by planting native grasses 3.23 76

3.9 Cost categories and estimated costs for woodland development in North Dakota 3.28 81

3.10 Habitat variables potentially affected by woodland development . 3.29 82

3.11 A summary of the habitat variables potentially affected by woodland development 3.36 89

4.1 Summary of burning impacts on productivity of grassland vegetation 4.3 93

4.2 Cost categories and estimated costs for burning native grassland 4.7 97

4.3 Habitat variables of native grassland potentially affected by burning 4.8 98

4.4 A summary of the habitat variables potentially affected by burning in native grassland 4.26 116

5.1 Estimated costs for fence construction and maintenance 5.4 123

5.2 Habitat variables potentially affected by grazing control 5.6 125

5.3 A summary of the habitat variables potentially affected by grazing control 5.18 137

6.1 Assumed design parameters and estimated costs for construction of a seasonal wetland or a semipermanent wetland in North Dakota 6.3 142

6.2 Cost categories and estimated costs for constructing small impoundments and level ditch ponds in the Dakota pothole region 6.4 143

6.3 Habitat variables potentially affected by construction of wetlands 6.6 145

6.4 A summary of the habitat variables potentially affected by construction of seasonal and/or semipermanent wetlands 6.15 154

6.5 Estimated costs for restoration of wetlands by wetland class in North Dakota 6.19 158

6.6 A summary of the habitat variables potentially affected by wetland restoration 6.27 166

Tables (Concluded)

Number Page

7.1 Itemized costs of constructing 0.4-ha islands in the Dakota pothole region 7.3 166

7.2 Itemized costs of constructing 0.003-ha islands in North Dakota 7.4 170

7.3 Habitat variables potentially affected by construction of islands 7.5 172

7.4 A summary of the habitat variables potentially affected by construction of islands 7.13 180

1. INTRODUCTION

BACKGROUND

There is an increasing need for predicting changes in wildlife populations or habitat quality for various species as a result of habitat management activities or mitigation efforts. Additionally, there is a need to evaluate the cost-effectiveness of habitat management activities in terms of the objectives of management (Lokemoen 1984). A knowledge of the consequences of habitat management, in terms of both habitat changes and economics, allows a manager or agency to select the most appropriate management measures to achieve the desired objectives.

One method of evaluating the effects of management actions on wildlife is through an assessment of population changes resulting from management (Lokemoen 1984). Another approach is to evaluate the changes in habitat, and then relate those changes to the potential of the habitat to support a given species. One method for assessing impacts to wildlife habitat is the Habitat Evaluation Procedures (U.S. Fish and Wildlife Service 1980), which requires input in the form of Habitat Suitability Indices (HSI) ranging from 0 (unsuitable habitat) to 1 (optimum habitat). The preferred approach to obtaining HSI values is through the use of habitat models that describe the relationships between habitat conditions and habitat suitability.

The Habitat Evaluation Procedures were used in an evaluation of selected wildlife impacts resulting from the Garrison Diversion Unit project in North Dakota (U.S. Department of the Interior 1982). Habitat models were developed and used to derive HSI's for seven wildlife species. The models were used to predict the impacts of project implementation as well as the impacts of management actions designed to mitigate project impacts. The difficulties encountered in these activities emphasized the need for guidance on linking the effects of habitat management actions to habitat suitability via the HSI models.

PURPOSE

The purposes of this paper are: (1) to present the mathematical relationships between selected management actions and habitat variables, and (2) to serve as a prototype to guide users in linking management actions to HSI models. Although there is an abundance of published literature that describes population responses to selected management actions, very little quantitative information exists that relates management actions to changes in habitat variables used in HSI models. Consequently, a number of major assumptions were necessary to develop the management models. The intended contribution of this effort is to provide a logical structure that can be followed in the development of management models that link management actions to habitat variables (including habitat area). The habitat variables can then be linked to habitat suitability for selected wildlife species through the use of HSI models.

SCOPE

This paper considers the habitat variables in HSI models for six of the seven wildlife species that were used in an evaluation of selected project impacts and mitigation efforts for the Garrison Diversion Unit study. The six species are the blue-winged teal (Anas discors), gadwall (Anas strepera), sharp-tailed grouse (Tympanuchus phasianellus), Baird's sparrow (Ammodramus bairdii), gray partridge (Perdix perdix), and muskrat (Ondatra zibethicus). HSI models for these species were developed by the Fish and Wildlife Service's National Ecology Center. The models describe presumed relationships between selected habitat variables and habitat suitability. The general relationships contained in the HSI models are shown in Figures 1.1 to 1.5.

The management actions included in this paper are those that were used in the mitigation plan for the Garrison Diversion Unit study. The management actions are classified in six general categories: (1) land acquisition, (2) upland vegetation development, (3) upland vegetation maintenance/management, (4) upland vegetation protection, (5) wetland development, and (6) island construction. The habitat variables that are included in this paper are based on the six HSI models described above; however, the management action models are not restricted to these six HSI models. The impacts of management actions on habitat variables are presented without regard to species' HSI models. Therefore, the management action models can be used to evaluate impacts on other wildlife species besides the six listed above, as long as the habitat variables in the new HSI models are included in the management models. The relationships between habitat variables and management actions are summarized in Table 1.1. Not all of the habitat variables included in Figures 1.1 to 1.5 are included in Table 1.1, because some habitat variables from the six HSI models were not impacted by any of the selected management actions.

Variables with a "+" in Table 1.1 are those that increase as the result of the corresponding management action, whereas those with a "-" are decreased by the management action. The direction of change refers only to the habitat variable (e.g., an increase or decrease in the percent herbaceous canopy cover). Direction of change for habitat suitability of a given species will depend on the functional relationships contained within a given HSI model.

BLANK PAGE

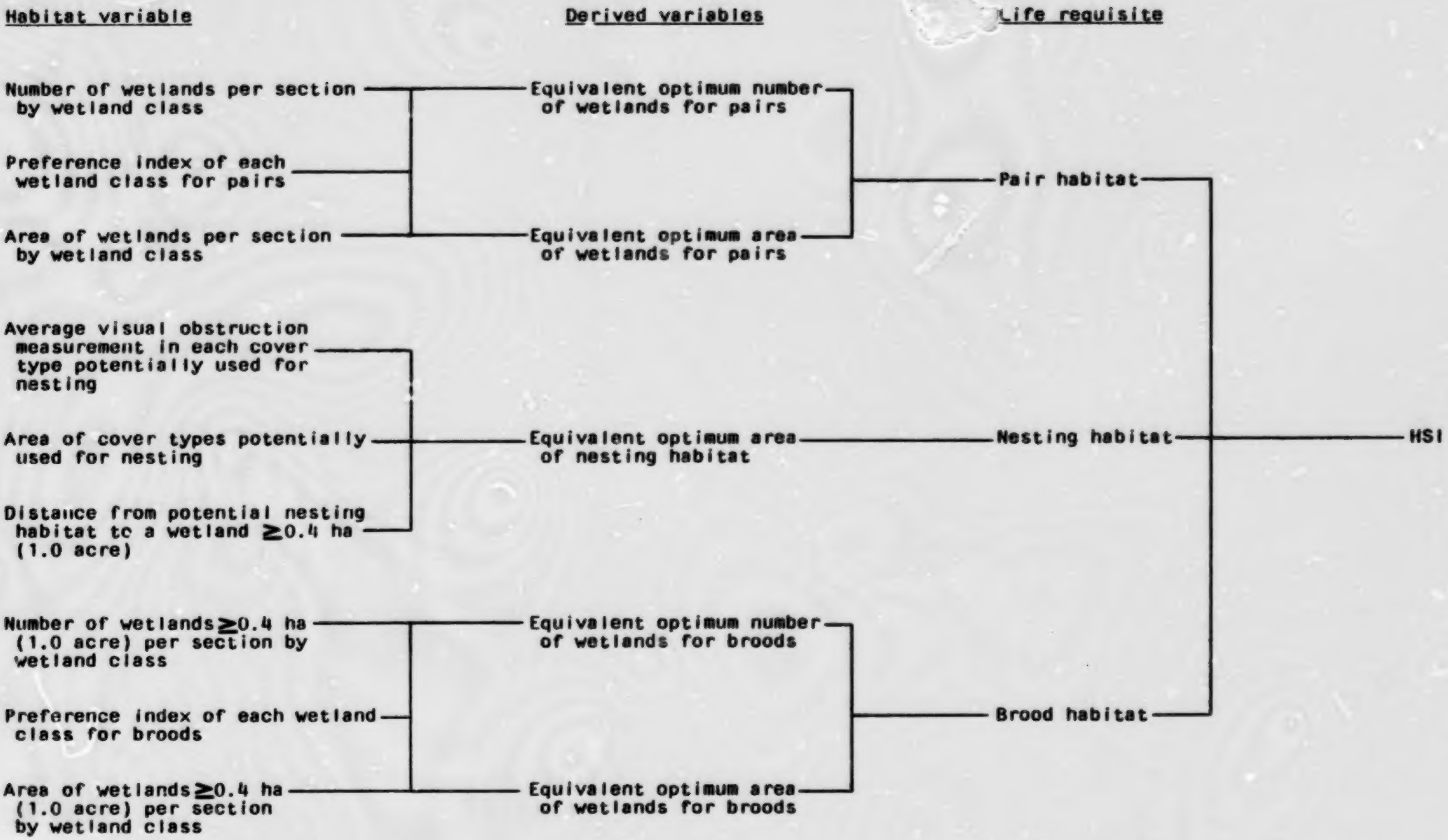

Habitat variable
Derived variables
Life requisite
Number of wetlands per section by wetland class
Preference index of each wetland class for pairs
Area of wetlands per section by wetland class
Equivalent optimum number of wetlands for pairs
Equivalent optimum area of wetlands for pairs
Pair habitat
Average visual obstruction measurement in each cover type potentially used for nesting
Area of cover types potentially used for nesting
Distance from potential nesting habitat to a wetland ≥0.4 ha (1.0 acre)
Equivalent optimum area of nesting habitat
Nesting habitat
HSI
Number of wetlands ≥0.4 ha (1.0 acre) per section by wetland class
Preference index of each wetland class for broods
Area of wetlands ≥0.4 ha (1.0 acre) per section by wetland class
Equivalent optimum number of wetlands for broods
Equivalent optimum area of wetlands for broods
Brood habitat

Figure 1.1. The relationships between habitat variables, derived variables, life requisites, and an HSI for the gadwall and blue-winged teal.

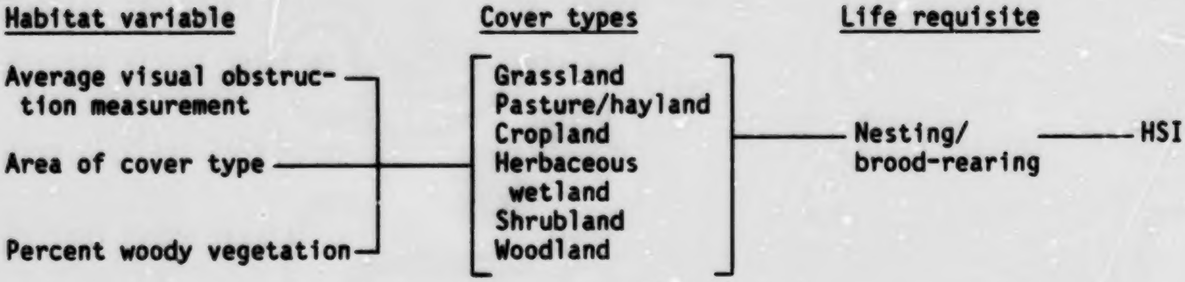

Habitat variable
Cover types
Life requisite
Average visual obstruction measurement
Area of cover type
Percent woody vegetation
Grassland
Pasture/hayland
Cropland
Herbaceous wetland
Shrubland
Woodland
Nesting/brood-rearing
HSI

Figure 1.2. Relationships of habitat variables, cover types, and life requisites in the sharp-tailed grouse HSI model.

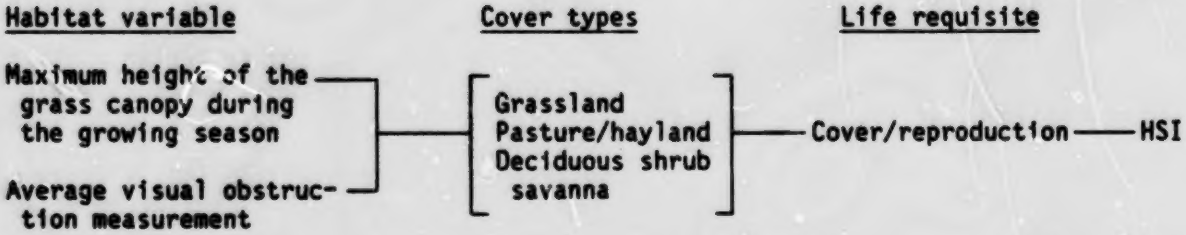

Habitat variable
Cover types
Life requisite
Maximum height of the grass canopy during the growing season
Average visual obstruction measurement
Grassland
Pasture/hayland
Deciduous shrub savanna
Cover/reproduction
HSI

Figure 1.3. Relationships of habitat variables, cover types, and life requisites in the Baird's sparrow HSI model.

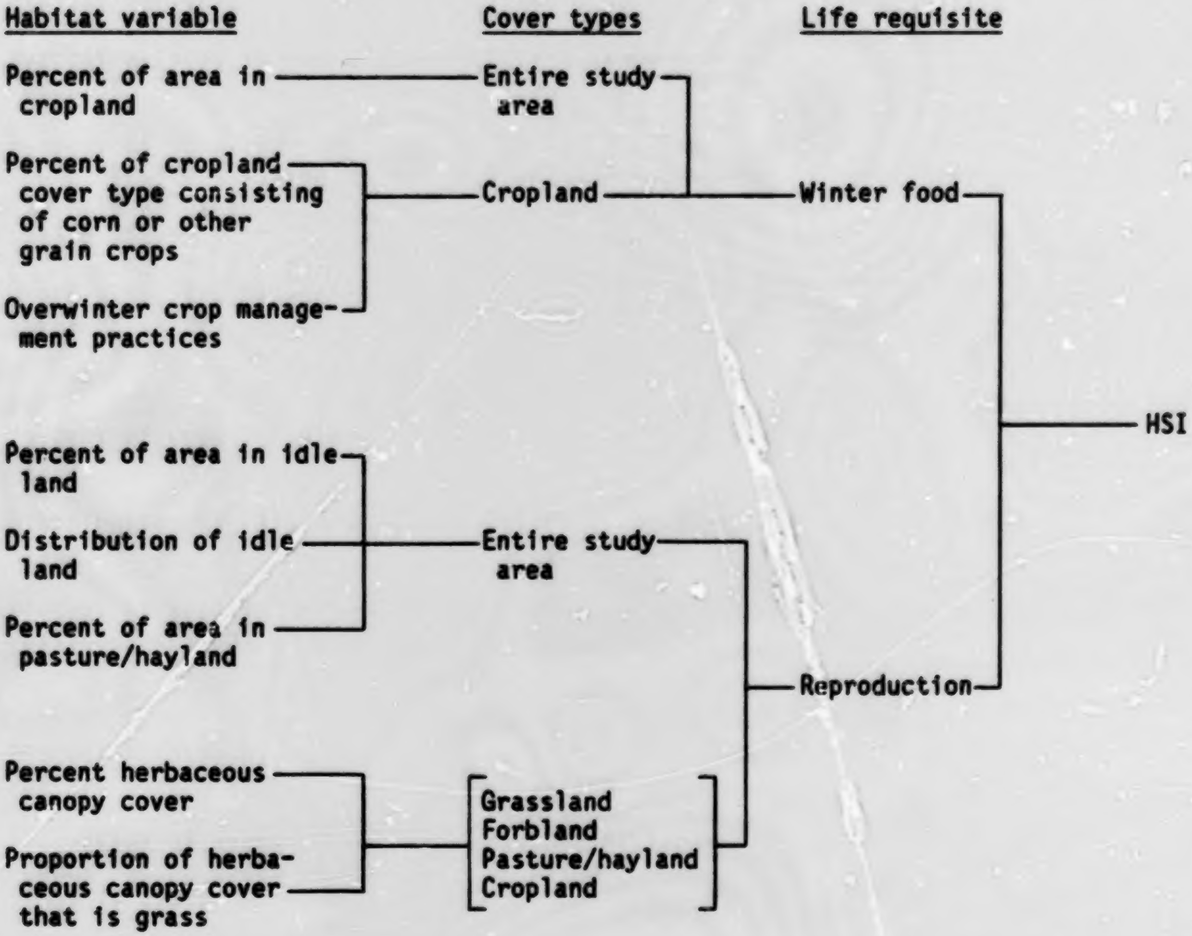

Habitat variable
Cover types
Life requisite
Percent of area in cropland
Entire study area
Percent of cropland cover type consisting of corn or other grain crops
Cropland
Winter food
Overwinter crop management practices
HSI
Percent of area in idle land
Distribution of idle land
Entire study area
Percent of area in pasture/hayland
Reproduction
Percent herbaceous canopy cover
Grassland
Forbland
Pasture/hayland
Cropland
Proportion of herbaceous canopy cover that is grass

Figure 1.4. Relationships of habitat variables, cover types, and life requisites in the gray partridge HSI model.

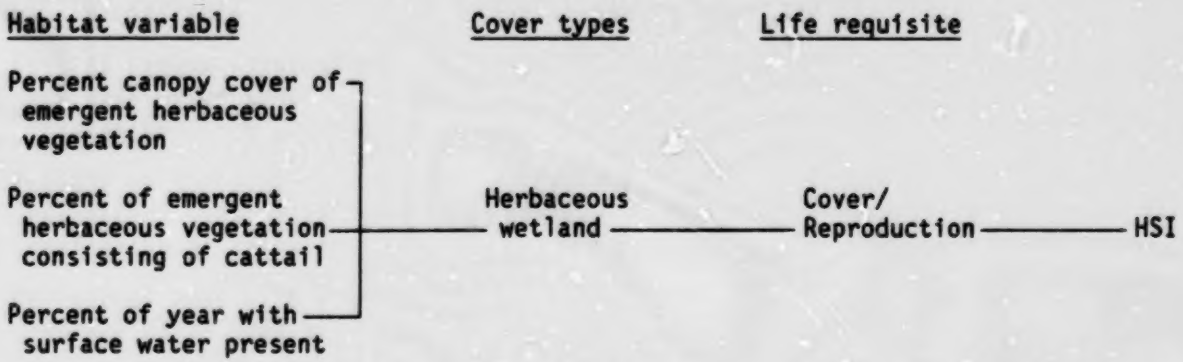

Habitat variable
Cover types
Life requisite
Percent canopy cover of emergent herbaceous vegetation
Percent of emergent herbaceous vegetation consisting of cattail
Percent of year with surface water present
Herbaceous wetland
Cover/ Reproduction
HSI

Figure 1.5. Relationships of habitat variables, cover types, and life requisites in the muskrat HSI model.

The mathematical functions describing the relationships between habitat variables and management actions are based on assumptions that were considered valid prior to 1985. At that time, wetland drainage for agricultural purposes was a common practice by landowners; one of the advantages of taking wetland easements assuming such land use practices is the maintenance of wetland area over time. However, the Food Security Act of 1985 contains provisions that will likely reduce the historical trend of wetland drainage and alter land use patterns. As a result, some of the assumptions contained in this document are no longer valid, although the approach to the problem of describing relationships between management and habitat conditions remains valid. This example illustrates the importance of clearly stating the assumptions upon which predictions of land use change are based. Changing social values and accompanying legislation must always be considered when attempting to make predictions of future conditions.

Management actions may occur in a number of surface cover types. In order to simplify the presentation of some of the functional relationships within the management action models, the models are built around a simplified classification system (Table 1.2). The classification of wetlands is based on the classification of Stewart and Kantrud (1971). The classification of cover types other than wetlands is a simplification of the system used on the Garrison Diversion Unit study. Users of these models can use any cover type classification system, as long as the functional relationships (i.e., curves and equations) used in the management action models are critically reviewed and revised accordingly.

Table 1.1. Matrix of relationships between selected management actions and habitat variables.

Habitat variable	Land Acquisition	a. Fee title	b. Easement	Upland Vegetation Development	a. Plant dense nesting cover	b. Plant native grasses	c. Woodland development	Upland Vegetation Maintenance/Mgmt.	a. Prescribed burning	Upland Vegetation Protection	a. Grazing control	Wetland Development	a. Construct seasonal wetlands	b. Construct semipermanent wetlands	c. Restore drained wetlands	Island Construction	a. Nesting islands
Number of wetlands of a specified wetland class[a]		+[b]	+										±	±	±		
Area of wetlands of a specified wetland class		+	+										±	±	±		-
Number of wetlands ≥0.4 ha of a specified wetland class		+	+										±	±	±		
Area of wetlands ≥0.4 ha of a specified wetland class		+	+										±	±	±		-
Area of specified non-wetland cover type		±	±		±	±	±		±		±		-	-	-		±
Percent of area in cropland		-	-		-	-	-						-	-	-		-
Percent of cropland cover type in corn or other grain crops		-			±	±	±						±	±	±		±
Percent of area in pasture/hayland		-	-				-				-		-	-	-		-
Percent of area in idle land		+	-		+	+	+				+		±	±	±		-
Distribution of idle cover		+	-		+	+	+				+		±	±	±		-
Percent woody vegetation							+										
Average visual obstruction measurement									±		+						

Table 1.1. (Concluded)

Habitat variable	Land Acquisition	a. Fee title	b. Easement	Upland Vegetation Development	a. Plant dense nesting cover	b. Plant native grasses	c. Woodland development	Upland Vegetation Maintenance/Mgmt.	a. Prescribed burning	Upland Vegetation Protection	a. Grazing control	Wetland Development	a. Construct seasonal wetlands	b. Construct semipermanent wetlands	c. Restore drained wetlands	Island Construction	a. Nesting islands
Percent herbaceous canopy cover									±		+						
Proportion of herbaceous canopy cover that is grass									±		+						
Distance to a wetland ≥0.4 ha					±	±	±				±		-	-	-		-
Maximum height of grass canopy									±		+						
Percent canopy cover of emergent herbaceous vegetation																	
Percent of emergent herbaceous vegetation consisting of cattail																	

[a] Wetland classes follow Stewart and Kantrud (1971) and are Ephemeral (Class I), Temporary (II), Seasonal (III), Semipermanent (IV), Permanent (V), and Alkali (VI).

[b] + indicates a potential increase in a variable due to management; - indicates a potential decrease; blank indicates no effect.

Table 1.2. Cover type classification system used in the management action models.

Wetlands[a,b]	Nonwetlands[b]
1. Ephemeral (Class I)	1. Tame grassland
2. Temporary (II)	2. Native grassland
3. Seasonal (III)	3. Cropland
4. Semipermanent (IV)	4. Shrubland
5. Permanent (V)	5. Woodland
6. Alkali (VI)	

[a] From Stewart and Kantrud 1971.

[b] The subscript i will be used to refer to wetland cover types, and the subscript j will be used to refer to nonwetland cover types. For example, NWij refers to the number of wetlands of class i constructed in nonwetland cover type j. Wetland cover types will range from 1 to 6 and correspond to the Classes I-VI used by Stewart and Kantrud (1971).

USE OF THE DOCUMENT

The relationships described in this paper are based on the list of variables in the HSI models for the six species previously described (Figures 1.1 to 1.5, Table 1.1). These relationships can be used to evaluate impacts of management actions on any species for which an HSI model is available, if the model includes habitat variables considered in this paper. The framework provided here may also be used to develop relationships for additional habitat variables or management actions.

Development and maintenance costs for each management action are presented. An average annual equivalent value (AAEV) for each action is not presented, since this will be a function of the selected discount rate and period of analysis. Costs can be amortized by using Equation 1.1 (Glenn and Barbour 1970):

$$\text{Amortization factor} = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad (1.1)$$

where n = the number of periods being considered, generally expressed in years

i = the interest rate at which compounding takes place over the period, n, expressed as a decimal fraction

ORGANIZATION

This paper is arranged by general categories of management actions. The functional relationships between management actions and habitat variables are presented for each action. Within each section, a subsection, Management Action Information, discusses the action's purpose, effects, maintenance requirements, and cost. Descriptions of the HSI models from which the list of habitat variables was developed are not included because such descriptions would imply a very narrow range of applicability of the management models, when the actual intent is to present the relationships between management actions and habitat variables in a broad framework applicable to a wide range of species. A second subsection, Habitat Management Model, presents the mathematical relationships between the management action and the affected habitat variables. The applicability and limitations of a management model are also presented in this subsection.

LITERATURE CITED

Glenn, B.P., and E. Barbour. 1970. A guide to using interest factors in economic analysis of water projects. U.S. Bur. Reclamation. 103 pp.

Lokemoen, J.L. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

Stewart, R.E., and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Bur. Sport Fish Wildl. Resour. Publ. 92. 47 pp.

U.S. Department of the Interior. 1982. Fish and Wildlife Mitigation and Enhancement Plan for Phase I - Garrison Diversion Unit, Pick-Sloan Missouri River Basin Program. Vol. 1: Committee Report. U.S. Department of the Interior and State of North Dakota. 42 pp.

U.S. Fish and Wildlife Service. 1980. Habitat evaluation procedures. 102 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv., Washington, DC. n.p.

2. LAND ACQUISITION

a. Fee Title

MANAGEMENT ACTION INFORMATION

Purpose

There are two reasons to acquire land by fee title as a management action. The first is to obtain rights to implement other management actions on the land (e.g., wetland construction, burning). The second is to preserve the habitat on the purchased land, thereby preventing future habitat disturbance or destruction. The first purpose should be considered as a preliminary step to other management actions, while the second should be considered as an end in itself.

Effects of Management Action

The beneficial impacts of fee title acquisition as a management action can only be evaluated by comparing conditions with purchase to conditions without purchase over time. For example, if wetlands within the area of purchase are being drained at a given rate (e.g., 2% per year), then fee title acquisition will allow the purchaser to prevent a predictable amount of drainage. As a result, habitat quantity and quality will be maintained at a higher level over time for wetland-dependent species than they would be without fee title purchase. Similarly, fee title purchase of native grassland habitat may prevent the eventual conversion of the grassland to cropland or to other land uses (e.g., intensive grazing) that are less desirable habitat for the species of interest.

Maintenance and Management

Fee title acquisition of land is considered to consist of only those activities involved in the actual purchase of the land. This includes location of suitable land, land appraisal, and transfer of title to the land. Activities such as fencing, trespass enforcement, or wetland management are considered as separate management actions made possible by fee title purchase of the land.

Labor and Materials

The labor involved in fee title acquisition includes time involved in land appraisal and actual transfer of title to the land. Location of willing sellers may also involve staff time by the purchasing agency.

011

The costs involved in land acquisition depend on a number of factors, such as location, access, type of soil, topography, current land use, and composition of surface cover types. In order to obtain an accurate cost for a parcel of land, the specific parcel should be delineated and appraised. Table 2.1 provides a summary of average costs estimated for various surface cover types in North Dakota. These are the types of information that should be estimated for specific acquisition activities rather than absolute anticipated costs. Costs of land acquisition by fee title are obviously very site specific, and appropriate cost information should be developed for each potential fee title purchase.

If land is to be purchased in order to obtain the right to implement other management actions, then the cost of land acquisition must also be included in the overall cost of management plans.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Land acquisition through fee title purchase can apply to any surface cover type or combination of surface cover types. The purpose of the acquisition may be as an end in itself (i.e., for preservation of specific cover types), or as a preliminary step to implementation of specific management actions, such as fencing, wetland construction, or planting vegetation.

Minimum management area. Land acquisition through fee title purchase can occur on any size parcel of land, although it is likely that land offered by owners will consist of several hectares at a minimum. Fee title purchase of small parcels (e.g., <2 ha) may occur in situations where the land is of unique biological value.

Model Description

Overview. This model describes the differences in selected habitat variables (Table 2.2) over time as the result of fee title purchase of land. These changes may reflect differences attributable to maintenance of existing habitats or differences resulting from changes in habitats due to natural succession. The latter situation refers specifically to passive land management, such as conversion of croplands to native grassland as the result of plant succession. Changes in habitat variables due to active management, such as wetland construction, planting of grasses, burning, or grazing control, are treated elsewhere (see Chapters 3 to 6). The variables in Table 2 2 do not include those variables that are not likely to change on fee title land without further active management.

The influence of fee title purchase on each of the variables listed in Table 2.2 is discussed below. The influence of fee title purchase on variables describing the area or number of wetland and nonwetland cover types (i.e., the first five variables in Table 2.2) is very similar. Therefore, the relationship is discussed in detail for the first of these variables and briefly for the remaining four variables.

012

Table 2.1. Estimated cost by selected surface cover types for land acquisition through fee title purchase in North Dakota.[a]

Surface cover type	Range of cost ($/0.4 ha)	Average cost ($/0.4 ha)
Native grassland	200-400	275
Tame grassland	300-500	400
Alfalfa	400-1000	550
Cropland	400-1000	550
Woodland (associated with grassland)	200-400	275
Woodland (associated with cropland)	400-1000	550

Wetlands	Associated with cropland average cost ($/0.4 ha)	Associated with pasture average cost ($/0.4 ha)
Temporary	550	275
Seasonal	330	250
Semipermanent	220	140
Permanent	140	100
Alkali	80	50

---

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

Table 2.2. Habitat variables potentially affected by fee title purchase of land.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Number of wetlands of a specified wetland class (NW_i)	X	
Area of wetlands of a specified wetland class (AW_i)	X	
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	X	
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	X	
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)		X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of fee title purchase of land and subsequent passive management compared to the same area without fee title purchase. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

Number of wetlands of a specified wetland class (NW_i). The primary purpose of purchasing wetlands is to prevent future drainage. The influence of fee title purchase on this variable is to maintain the number of wetlands at current levels. Construction or restoration of wetlands are considered as influences separate from purchase of wetlands (see Chapter 6). Determination of an average annual change in this variable requires comparison of future conditions with and without purchase. Figure 2.1 illustrates an example comparison for this variable with and without purchase. The number of wetlands of a given class is assumed to remain constant at NWB_i over time with purchase (Figure 2.1). Without purchase, wetland drainage is assumed to occur at a rapid rate initially, with a lower drainage rate after a specific time (t_x in Figure 2.1). The area between the two curves depicting conditions with and without purchase is the difference due to purchase (shaded area in Figure 2.1). The average annual difference in the number of wetlands of a given class due to purchase can be determined by Equation 2.1a.

$$XNW_i = \left[\sum_{\ell=1}^{m} NWWP_{i,\ell} - \sum_{\ell=1}^{m} NWOP_{i,\ell} \right] / m \qquad (2.1a)$$

where XNW_i = the average annual difference between the number of wetlands of class i with an action and the number of wetlands of class i without an action (in this case, with and without purchase)

$NWWP_{i,\ell}$ = the number of wetlands of class i present in year ℓ with land purchase

$NWOP_{i,\ell}$ = the number of wetlands of class i present in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

Equation 2.1a requires an estimate of the number of wetlands available for each year of the project life with and without land purchase. An estimate of the average annual difference can be made by projecting conditions of the variable for selected target years (a minimum of 2 years, i.e., when $\ell=1$ and $\ell=m$), as in Equation 2.1b.

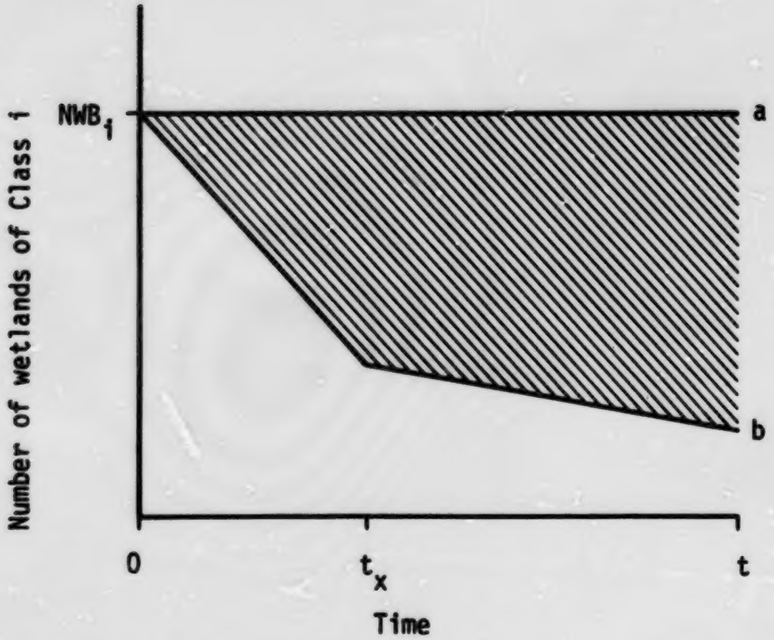


Figure 2.1. Conceptual comparison of the number of wetlands of class i available over time with (curve a) and without (curve b) purchase.

$$XNW_i = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWWP_{i,2,\ell} + NWWP_{i,1,\ell})/2]\right]/m \qquad (2.1b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWOP_{i,2,\ell} + NWOP_{i,1,\ell})/2]\right]/m$$

where XNW_i = the average annual difference between the number of wetlands of class i with an action and the number of wetlands of class i without an action (in this case, with and without purchase)

t = the number of time intervals being evaluated, i.e., the number of selected years

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$NWWP_{i,1,\ell}$ = the number of wetlands of class i present at the beginning of time interval ℓ with land purchase

016

$NWWP_{i,2,\ell}$ = the number of wetlands of class i present at the end of time interval ℓ with land purchase

$NWOP_{i,1,\ell}$ = the number of wetlands of class i present at the beginning of time interval ℓ without land purchase

$NWOP_{i,2,\ell}$ = the number of wetlands of class i present at the end of time interval ℓ without land purchase

m = the period of analysis, i.e., the life of the project

If the number of wetlands present in the future under conditions of land purchase is assumed to remain constant, then Equation 2.1b can be simplified to Equation 2.1c.

$$XNW_i = NW_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWOP_{i,2,\ell} + NWOP_{i,1,\ell})/2] \right] / m \qquad (2.1c)$$

where $NW_{i,B}$ = the number of wetlands of class i for a given base (e.g., baseline conditions prior to land purchase)

All other variables are as described above (Equation 2.1b)

Estimates of the number of wetlands present under future conditions can be made based on drainage trends. For example, wetlands of class i may currently be drained at a rate of 3% per year. Such figures are site specific but should be easily obtained. Estimates must be made for each class of wetlands, since significantly different drainage rates likely exist between shallow, temporary wetlands and deep, more permanent wetlands.

Area of wetlands of a specified wetland class (AW_i). The potential influence of land purchase on this variable is similar to that discussed previously for the number of wetlands of a specified wetland class. The logic involved in comparing conditions of this variable with and without land purchase is identical to that described for number of wetlands and will not be repeated in order to avoid redundancy.

017

The average annual difference in the area of wetlands of a specified wetland class due to purchase can be determined by Equation 2.2a.

$$XAW_i = \left[\sum_{\ell=1}^{m} AWWP_{i,\ell} - \sum_{\ell=1}^{m} AWOP_{i,\ell} \right] / m \qquad (2.2a)$$

where XAW_i = the average annual difference between the area of wetlands of class i with an action and the area of wetlands of class i without an action (in this case, with and without purchase)

$AWWP_{i,\ell}$ = the area of wetlands of class i present in year ℓ with land purchase

$AWOP_{i,\ell}$ = the area of wetlands of class i present in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

An estimate of the average annual difference in this variable with and without purchase can be made with Equation 2.2b, which requires estimates of the variable for selected target years only.

$$XAW_i = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWWP_{i,2,\ell} + AWWP_{i,1,\ell})/2] \right] / m \qquad (2.2b)$$
$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWOP_{i,2,\ell} + AWOP_{i,1,\ell})/2] \right] / m$$

where XAW_i = the average annual difference between the area of wetlands of class i with an action and the area of wetlands of class i without an action (in this case, with and without purchase)

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$AWWP_{i,1,\ell}$ = the area of wetlands of class i present at the beginning of time interval ℓ with land purchase

$AWWP_{i,2,\ell}$ = the area of wetlands of class i present at the end of time interval ℓ with land purchase

$AWOP_{i,1,\ell}$ = the area of wetlands of class i present at the beginning of time interval ℓ without land purchase

$AWOP_{i,2,\ell}$ = the area of wetlands of class i present at the end of time interval ℓ without land purchase

m = the period of analysis, i.e., the life of the project

Equation 2.2b can be simplified to Equation 2.2c if it is assumed that the area of wetlands of a given class will remain constant as the result of land purchase.

$$XAW_i = AW_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [((AWOP_{i,2,\ell} + AWOP_{i,1,\ell})/2] \right] /m \qquad (2.2c)$$

where $AW_{i,B}$ = the area of wetlands of class i for a given base (e.g., baseline conditions prior to land purchase)

All other variables are as described above (Equation 2.2b).

Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i). The influence of land purchase on this variable is identical to that discussed for the number of wetlands of a specified wetland class (NW_i), with the single exception that only those wetlands with a minimum area of 0.4 ha are considered. An average annual difference between this variable with and without land purchase can be determined by Equations 2.3a-c. Equation 2.3a requires an estimate of the variable for each year of the period of analysis. Equation 2.3b requires estimates for selected target years. Equation 2.3c also requires target year estimates, but assumes that the number of wetlands ≥0.4 ha will remain unchanged under conditions of land purchase.

$$XNWL_i = \left[\sum_{\ell=1}^{m} NWLWP_{i,\ell} - \sum_{\ell=1}^{m} NWLOP_{i,\ell} \right] / m \tag{2.3a}$$

$$\begin{aligned} XNWL_i = {} & \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLWP_{i,2,\ell} + NWLWP_{i,1,\ell})/2] \right] / m \\ & - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLOP_{i,2,\ell} + NWLOP_{i,1,\ell})/2] \right] / m \end{aligned} \tag{2.3b}$$

$$XNWL_i = NWL_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLOP_{i,2,\ell} + NWLOP_{i,1,\ell})/2] \right] / m \tag{2.3c}$$

where $XNWL_i$ = the average annual difference between the number of wetlands ≥0.4 ha of class i with an action and the number of wetlands ≥0.4 ha of class i without an action (in this case, with and without purchase)

$NWLWP_{i,\ell}$ = the number of wetlands ≥0.4 ha of class i present in year ℓ with land purchase

$NWLOP_{i,\ell}$ = the number of wetlands ≥0.4 ha of class i present in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$NWLWP_{i,1,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ with land purchase

$NWLWP_{i,2,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the end of time interval ℓ with land purchase

$NWLOP_{i,1,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ without land purchase

$NWLOP_{i,2,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the end of time interval ℓ without land purchase

$NWL_{i,B}$ = the number of wetlands of class i for a given base (e.g., baseline conditions prior to land purchase)

Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i). The influence of land purchase on this variable is identical to that discussed for the area of wetlands of a specified wetland class (AW_i), with the single exception that only those wetlands with a minimum area of 0.4 ha are considered. An average annual difference between this variable with and without land purchase can be determined by Equations 2.4a-c. Equation 2.4a requires an estimate of the variable for each year of the period of analysis. Equation 2.4b requires estimates for selected target years. Equation 2.4c also requires target year estimates, but assumes that the area of wetlands ≥0.4 ha will remain unchanged under conditions of land purchase.

$$XAWL_i = \left[\sum_{\ell=1}^{m} AWLWP_{i,\ell} - \sum_{\ell=1}^{m} AWLOP_{i,\ell}\right]/m \tag{2.4a}$$

$$\begin{aligned} XAWL_i = {} & \left[\sum_{\ell=1}^{t} (T_{2,\ell}-T_{1,\ell}) \times [(AWLWP_{i,2,\ell} + AWLWP_{i,1,\ell})/2]\right]/m \\ & - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWLOP_{i,2,\ell} + AWLOP_{i,1,\ell})/2]\right]/m \end{aligned} \tag{2.4b}$$

$$XAWL_i = AWL_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWLOP_{i,2,\ell} + AWLOP_{i,1,\ell})/2]\right]/m \tag{2.4c}$$

where $XAWL_i$ = the average annual difference between the area of wetlands ≥0.4 ha of class i with an action and the area of wetlands ≥0.4 ha of class i without an action (in this case, with and without land purchase)

$AWLWP_{i,\ell}$ = the area of wetlands ≥0.4 ha of class i present in year ℓ with land purchase

$AWLOP_{i,\ell}$ = the area of wetlands ≥0.4 ha of class i present in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

021

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$AWLWP_{i,1,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ with land purchase

$AWLWP_{i,2,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the end of time interval ℓ with land purchase

$AWLOP_{i,1,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ without land purchase

$AWLOP_{i,2,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the end of time interval ℓ without land purchase

$AWL_{i,B}$ = the area of wetlands of class i for a given base (e.g., baseline conditions prior to land purchase)

Area of specified nonwetland cover type (ACT_j). The influence of land purchase alone (i.e., without additional active management practices) on cover types will most likely be to maintain existing cover types at their baseline areas. Depending on the cover type, the future area without purchase may be greater than (Figure 2.2a) or less than (Figure 2.2b) the baseline conditions. Without land purchase, cropland and tame grassland may increase as a result of an economic incentive of increasing the area of such cover types. Such an increase is at the expense of other nonwetland and wetland cover types. Therefore, the net average annual difference in cover type area due to land purchase may be either positive or negative, since the difference is determined by subtracting the without purchase conditions from the with purchase conditions. Equations 2.5a-c can be used to estimate the average annual difference in cover type area due to land purchase. Equation 2.5a requires annual estimates, whereas Equation 2.5b requires estimates for selected target years. Equation 2.5c also is based on target year information, but with the assumption that the area of the cover type will not change over time with land purchase.

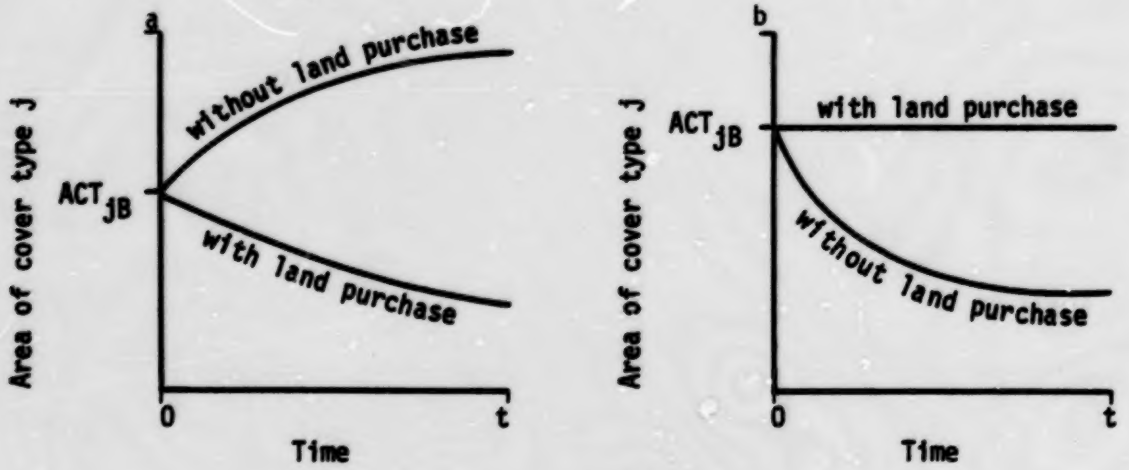

a
without land purchase
with land purchase
Area of cover type j
ACT_{jB}
0
t
Time
b
with land purchase
without land purchase
Area of cover type j
ACT_{jB}
0
t
Time

Figure 2.2. Conceptual comparison of change in cover type area over time with and without land purchase. Figure 2.2a represents cover types expected to increase without land purchase; Figure 2.2b represents cover types expected to decrease without land purchase.

$$XACT_j = \left[\sum_{\ell=1}^{m} ACTWP_{j,\ell} - \sum_{\ell=1}^{m} ACTOP_{j,\ell}\right]/m \qquad (2.5a)$$

$$XACT_j = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTWP_{j,2,\ell} + ACTWP_{j,1,\ell})/2]\right]/m \qquad (2.5b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTOP_{j,2,\ell} + ACTOP_{j,1,\ell})/2]\right]/m$$

$$XACT_j = ACT_{j,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTOP_{j,2,\ell} + ACTOP_{j,1,\ell})/2]\right]/m \qquad (2.5c)$$

where $XACT_j$ = the average annual difference between the area of cover type j with an action and the area of cover type j without an action (in this case, with and without purchase)

023

$ACTWP_{j,\ell}$ = the area of cover type j present in year ℓ with land purchase

$ACTOP_{j,\ell}$ = the area of cover type j present in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$ACTWP_{j,1,\ell}$ = the area of cover type j present at the beginning of time interval ℓ with land purchase

$ACTWP_{j,2,\ell}$ = the area of cover type j present at the end of time interval ℓ with land purchase

$ACTOP_{j,1,\ell}$ = the area of cover type j present at the beginning of time interval ℓ without land purchase

$ACTOP_{j,2,\ell}$ = the area of cover type j present at the end of time interval ℓ without land purchase

$ACT_{j,B}$ = the area of cover type j for a given base (e.g., baseline conditions prior to land purchase)

Percent of area in cropland (PC). Land purchase without additional active management practices will most likely maintain or reduce the baseline condition of this variable. However, the proportion of an area in cropland will most likely increase over time without land purchase (as depicted previously in Figure 2.2a). The most likely net difference over time is a reduction in the average annual value for this variable with land purchase. This difference can be estimated with Equations 2.6a-c. As with previous variables, the overall estimate can be made based on individual annual estimates (Equation 2.6a), with selected target year estimates (Equation 2.6b), or with selected target years coupled with an assumption of no change in the variable over time with land purchase (Equation 2.6c).

$$XPC = \left[\sum_{\ell=1}^{m} PCWP_{\ell} - \sum_{\ell=1}^{m} PCOP_{\ell}\right]/m \tag{2.6a}$$

$$XPC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCWP_{2,\ell} + PCWP_{1,\ell})/2]\right]/m \qquad (2.6b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCOP_{2,\ell} + PCOP_{1,\ell})/2]\right]/m$$

$$XPC = PC_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCOP_{2,\ell} + PCOP_{1,\ell})/2]\right]/m \qquad (2.6c)$$

where XPC = the average annual difference between the proportion of an area in cropland with an action and the proportion of an area in cropland without an action (in this case, with and without purchase)

$PCWP_\ell$ = the proportion of an area in cropland in year ℓ with land purchase

$PCOP_\ell$ = the proportion of an area in cropland in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PCWP_{1,\ell}$ = the proportion of an area in cropland at the beginning of time interval ℓ with land purchase

$PCWP_{2,\ell}$ = the proportion of an area in cropland at the end of time interval ℓ with land purchase

$PCOP_{1,\ell}$ = the proportion of an area in cropland at the beginning of time interval ℓ without land purchase

$PCOP_{2,\ell}$ = the proportion of an area in cropland at the end of time interval ℓ without land purchase

PC_B = the proportion of an area in cropland for a given base (e.g., baseline conditions prior to land purchase)

Future conditions can best be estimated based on current and projected land use trends. For example, if cropland acreage in a given area has been increasing at a known rate, then that rate may be applied to determine the proportion of cropland present at any point during the period of analysis.

Percent of cropland cover type in corn or other grain crops (PCG). As described above, cropland area is most likely to increase over time without land purchase, as the result of economic incentives of crop production. The composition of the increased crop production, however, is a function of market conditions. If future markets favor corn and other grain crops, and if purchase is assumed to maintain current conditions of cropland composition, then the effect of land purchase is to maintain a lower proportion of the cropland in corn and other grain crops over time than would exist withouth land purchase (as depicted in Figure 2.2a). If, on the other hand, future market conditions favor crops other than corn and other grains, and if land purchase is assumed to maintain current conditions of cropland composition, then the effect of land purchase is to maintain a higher proportion of cropland in corn and other grain crops over time than would exist without land purchase (as depicted in Figure 2.2b). A third possibility is that the future increase in cropland will be identical in composition to the baseline conditions. In this case, land purchase will have no effect on the proportion of cropland in corn or other grain crops, although there will be a difference in cropland area with and without land purchase. The net difference in this variable due to land purchase can be estimated with: (1) Equation 2.7a, which requires annual estimates of the variables; (2) Equation 2.7b, which requires estimates for selected target years; or (3) Equation 2.7c, which also uses target year estimates, but with the assumption of no change in the variable over time with land purchase.

$$XPCG = \left[\sum_{\ell=1}^{m} PCGWP_{\ell} - \sum_{\ell=1}^{m} PCGOP_{\ell}\right]/m \tag{2.7a}$$

$$\begin{aligned} XPCG = {} & \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCGWP_{2,\ell} + PCGWP_{1,\ell})/2]\right]/m \\ & - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCGOP_{2,\ell} + PCGOP_{1,\ell})/2]\right]/m \end{aligned} \tag{2.7b}$$

$$XPCG = PCG_{B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCGOP_{2,\ell} + PCGOP_{1,\ell})/2]\right]/m \tag{2.7c}$$

where $XPCG$ = the average annual difference between the proportion of the cropland cover type in corn or other grain crops with an action and the proportion of the cropland cover type in corn or other grain crops without an action (in this case, with and without purchase)

$PCGWP_{\ell}$ = the proportion of the cropland cover type in corn or other grain crops in year ℓ with land purchase

$PCGOP_{\ell}$ = the proportion of the cropland cover type in corn or other grain crops in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PCGWP_{1,\ell}$ = the proportion of the cropland cover type in corn or other grain crops at the beginning of time interval ℓ with land purchase

$PCGWP_{2,\ell}$ = the proportion of the cropland cover type in corn or other grain crops at the end of time interval ℓ with land purchase

$PCGOP_{1,\ell}$ = the proportion of the cropland cover type in corn or other grain crops at the beginning of time interval ℓ without land purchase

$PCGOP_{2,\ell}$ = the proportion of the cropland cover type in corn or other grain crops at the end of time interval ℓ without land purchase

PCG_{B} = the proportion of the cropland cover type in corn or other grain crops for a given base (e.g., baseline conditions prior to land purchase)

Percent of area in pasture/hayland (PPH). This variable is an estimate of the proportion of an area supporting the land uses of grazing or mowing. Pasture/hayland is not considered as a distinct cover type. Rather, pasture/hayland results from certain land uses in tame or native grasslands. Functionally, the influence of land purchase on this variable is similar to the influence of land purchase on the percent of an area in cropland (Equations 2.6a-c). That is, land purchase without additional management (such as fencing or changes in stocking rates) will hold the proportion of an area in pasture/hayland constant. Without land purchase, the percent of an area in pasture/hayland will most likely increase (a relationship depicted in Figure 2.2a).

Therefore, land purchase will result in a net negative difference in the level of this variable. This difference can be estimated with: (1) Equation 2.8a, which requires annual estimates of the variable; (2) Equation 2.8b, which requires estimates for selected target years; or (3) Equation 2.8c, which also uses target year estimates but with the assumption of no change in the variable over time with land purchase.

$$XPPH = \left[\sum_{\ell=1}^{m} PPHWP_{\ell} - \sum_{\ell=1}^{m} PPHOP_{\ell}\right]/m \tag{2.8a}$$

$$\begin{aligned} XPPH = {} & \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHWP_{2,\ell} + PPHWP_{1,\ell})/2]\right]/m \\ & - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHOP_{2,\ell} + PPHOP_{1,\ell})/2]\right]/m \end{aligned} \tag{2.8b}$$

$$XPPH = PPH_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHOP_{2,\ell} + PPHOP_{1,\ell})/2]\right]/m \tag{2.8c}$$

where $XPPH$ = the average annual difference between the proportion of an area in pasture/hayland land uses with an action and the proportion of an area in pasture/hayland land uses without an action (in this case, with and without purchase)

$PPHWP_{\ell}$ = the proportion of an area in pasture/hayland land uses in year ℓ with land purchase

$PPHOP_{\ell}$ = the proportion of an area in pasture/hayland land uses in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PPHWP_{1,\ell}$ = the proportion of an area in pasture/hayland land uses at the beginning of time interval ℓ with land purchase

$PPHWP_{2,\ell}$ = the proportion of an area in pasture/hayland land uses at the end of time interval ℓ with land purchase

$PPHOP_{1,\ell}$ = the proportion of an area in pasture/hayland land uses at the beginning of time interval ℓ without land purchase

$PPHOP_{2,\ell}$ = the proportion of an area in pasture/hayland land uses at the end of time interval ℓ without land purchase

PPH_B = the proportion of an area in pasture/hayland land uses for a given base (e.g., baseline conditions prior to land purchase)

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types, including tame grassland, native grassland, shrubland, and woodland. If it is assumed that the area in crops or pasture/hayland will increase over time without land purchase, then the amount of idle land can be expected to decrease over time without land purchase. Therefore, land purchase results in a greater amount of idle land available over time compared to the same land without purchase for wildlife management purposes (Figure 2.2b). The average annual difference in this variable between with purchase and without purchase conditions can be estimated with: (1) Equation 2.9a, which requires annual estimates of the variable; (2) Equation 2.9b, which requires estimates for selected target years; and (3) Equation 2.9c, which also uses target year estimates, but with the assumption of no change in the variable over time with land purchase.

$$XPIL = \left[\sum_{\ell=1}^{m} PILWP_\ell - \sum_{\ell=1}^{m} PILOP_\ell \right] / m \tag{2.9a}$$

$$XPIL = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILWP_{2,\ell} + PILWP_{1,\ell})/2] \right] / m - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILOP_{2,\ell} + PILOP_{1,\ell})/2] \right] / m \tag{2.9b}$$

$$XPIL = PIL_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILOP_{2,\ell} + PILOP_{1,\ell})/2] \right] / m \tag{2.9c}$$

where $XPIL$ = the average annual difference between the percent of an area in idle land with an action and the percent of an area in idle land without an action (in this case, with and without purchase)

$PILWP_{\ell}$ = the percent of an area in idle land in year ℓ with land purchase

$PILOP_{\ell}$ = the percent of an area in idle land in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PILWP_{1,\ell}$ = the percent of an area in idle land at the beginning of time interval ℓ with land purchase

$PILWP_{2,\ell}$ = the percent of an area in idle land at the end of time interval ℓ with land purchase

$PILOP_{1,\ell}$ = the percent of an area in idle land at the beginning of time interval ℓ without land purchase

$PILOP_{2,\ell}$ = the percent of an area in idle land at the end of time interval ℓ without land purchase

PIL_B = the percent of an area in idle land for a given base (e.g., baseline conditions prior to land purchase)

Future conditions can best be estimated based on current and projected land use trends. For example, if idle land in a given area has been decreasing at a known rate, then that rate may be applied to determine the proportion of idle land present at any point during the period of analysis.

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km^2 sample area that contain or border idle habitat, defined as habitat that is not grazed or hayed, or does not support crops. Fee title purchase of land without additional active management will most likely maintain this variable at a constant level equal to that existing at the time of purchase. However, without land purchase it is likely that the number of 4-ha cells/2.59 km^2 with idle cover will decrease as the result of an increase in cropland and pasture/hayland (as depicted in Figure 2.2b). The effect of land purchase on this variable is a greater distribution of idle cover available over time than without land purchase. This difference can be estimated with: (1) Equation 2.10a, which requires annual estimates of the variable; (2) Equation 2.10b, which requires estimates for selected target years; and (3) Equation 2.10c, which also uses target year estimates, but with the assumption of no change in the variable over time with land purchase.

$$XDIC = \left[\sum_{\ell=1}^{m} DICWP_{\ell} - \sum_{\ell=1}^{m} DICOP_{\ell} \right] / m \qquad (2.10a)$$

$$XDIC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICWP_{2,\ell} + DICWP_{1,\ell})/2] \right] / m \qquad (2.10b)$$
$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICOP_{2,\ell} + DICOP_{1,\ell})/2] \right] / m$$

$$XDIC = DIC_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICOP_{2,\ell} + DICOP_{1,\ell})/2] \right] / m \qquad (2.10c)$$

where XDIC = the average annual difference between the distribution of idle cover with an action and the distribution of idle cover without an action (in this case, with and without purchase)

$DICWP_{\ell}$ = the distribution of idle cover in year ℓ with land purchase

$DICOP_{\ell}$ = the distribution of idle cover in year ℓ without land purchase

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$DICWP_{1,\ell}$ = the distribution of idle cover at the beginning of time interval ℓ with land purchase

$DICWP_{2,\ell}$ = the distribution of idle cover at the end of time interval ℓ with land purchase

$DICOP_{1,\ell}$ = the distribution of idle cover at the beginning of time interval ℓ without land purchase

$DICOP_{2,\ell}$ = the distribution of idle cover at the end of time interval ℓ without land purchase

DIC_B = the distribution of idle cover for a given base (e.g., baseline conditions prior to land purchase)

The most accurate way of measuring the distribution of idle cover in future years without purchase (i.e., $DICOP_\ell$) is to use a grid overlay on a map of projected cover types. A simpler means of estimating the distribution of idle cover is to decrease the variable by the same proportion that the area of idle cover is decreased (i.e., the increased amount of area converted to cropland or pasture/hayland at year ℓ). For example, if the area of cropland and pasture/hayland at year ℓ has increased from baseline conditions by 15%, then the distribution of idle cover can be decreased by 15% from the baseline distribution. This relationship is expressed mathematically in Equation 2.11.

$$DICOP_\ell = DIC_B - \left[\frac{(ACOP_\ell + APHOP_\ell) - (AC_B + APH_B)}{\text{Total study area}} \times DIC_B \right] \qquad (2.11)$$

where $DICOP_\ell$ = the distribution of idle cover in year ℓ without land purchase

DIC_B = the distribution of idle cover for a given base (e.g., baseline conditions prior to land purchase)

$ACOP_\ell$ = the area of cropland at year ℓ without land purchase

$APHOP_\ell$ = the area of pasture/hayland at year ℓ without land purchase

AC_B = the area of cropland at baseline conditions

APH_B = the area of pasture/hayland at baseline conditions

Model Relationships

The presumed relationships between fee title purchase of land and a number of habitat variables were described in the preceding section. The primary influence of fee title purchase of land is assumed to be on the absolute or relative area of cover types or land uses. Habitat variables describing the physical characteristics of vegetation (e.g., herbaceous canopy cover or grass height) are not considered to be directly influenced by varying amounts of fee title purchase of land.

Table 2.3 presents a summary of the variables affected by this management action and a reference to the equations that are used to estimate the influence of fee title purchase on the selected variables.

Table 2.3. A summary of the habitat variables potentially affected by fee title purchase of land.

Variable (acronym)	Equation	Page(s)
Number of wetlands of a specified wetland class (NW_i)	2.1a-c	2.5-2.7
Area of wetlands of a specified wetland class (AW_i)	2.2a-c	2.8-2.9
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	2.3a-c	2.10
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	2.4a-c	2.11
Area of specified nonwetland cover type (ACT_j)	2.5a-c	2.13
Percent of area in cropland (PC)	2.6a-c	2.14-2.15
Percent of cropland cover type in corn or other grain crops (PCG)	2.7a-c	2.16
Percent of the area in pasture/hayland (PPH)	2.8a-c	2.18
Percent of the area in idle land (PIL)	2.9a-c	2.19
Distribution of idle cover (DIC)	2.10a-c	2.21

Application of the Model

This model can be used to evaluate the influence of fee title purchase of land on selected variables describing available habitat. The model can be used in management gaming or in the evaluation of mitigation or management plans. The effects of land purchase on habitat variables can only be determined by comparing future conditions for an area with and without land purchase. Such projections of land use and cover type changes should consider current and historical trends and are obviously site specific.

Information that must be provided by a model user before using the equations in this model is as follows.

1. Baseline conditions for all variables considered in this model (Table 2.3).

2. Area of each cover type under conditions of with and without fee title purchase either for each year of the period of analysis, or for selected target years.

3. Number and area of wetlands, by wetland class, under conditions of with and without fee title purchase either for each year of the period of analysis, or for selected target years. This information is needed by wetland class for all wetlands and for wetlands ≥0.4 ha.

4. Total area in pasture or hayland land uses under conditions of with and without fee title purchase for either each year of the period of analysis, or for selected target years.

5. Total area that is not in crops, hayed, or grazed by domestic livestock under conditions of with and without fee title purchases either for each year of the period of analysis, or for selected target years.

2. LAND ACQUISITION
b. Easement

MANAGEMENT ACTION INFORMATION

Purpose

Easements can be taken in any cover type or combination of types to secure specified rights. Easements are recorded in county records and are binding on all subsequent landowners during the term of the contract.

Effects of Management Action

Easements are typically taken on wetlands and are designed to protect wetlands from being burned, drained, leveled, or filled for a given period of time. This model, therefore, is restricted to wetland cover types. The primary purpose of wetland easements is to maintain existing wetlands over a period of time. In contrast to fee title purchase, no management rights are acquired with easements. Landowners retain overall use and control of the wetland areas subject only to the burn, drain, level, and fill restrictions of the easement contract. The agency taking the easement maintains the right of access for inspection and enforcement purposes.

The beneficial impacts of wetland easements to habitat variables and, therefore, to wildlife, can only be evaluated by comparing habitat conditions with easement to habitat conditions without easement. For example, if wetlands within the area of the easement are being drained at a given rate, then wetland easements will result in more wetlands and wetland area over time. As a result, habitat quantity and quality will be maintained at a higher level over time for wetland dependent wildlife.

Maintenance and Management

Wetland easements do not include rights to management other than for inspection and enforcement. Initial activities involved in obtaining wetland easements include location of sellers, land appraisal and survey, and the legal paperwork of documenting the easements. Annual inspection and possibly enforcement are activities beyond the initial easement process.

Labor and Materials

The labor involved in obtaining wetland easements includes the time involved in land appraisal and the documentation of the easements. Location of sellers may also involve staff time by the agency taking the easements.

The cost involved in obtaining easements depends on a number of factors such as location, access, and wetland types, area, and density. Larger wetlands or alkaline wetlands are usually impractical to drain for agricultural purposes and are, therefore, less likely to be lost to drainage without easements. Based on information collected for the Garrison Diversion Unit study in North Dakota[1], the estimated cost per wetland acre for an easement will fall within a range of 45% to 60% of the average per acre fee title value of the total property on which the wetlands occur. The estimated cost can be determined by multiplying the total per acre property value by the appropriate percent and by the wetland area (i.e., value/acre x percent of total/easement x wetland area). An appraisal fee (estimated as $15/acre for the Garrison Diversion Unit study) should also be included in any easement cost estimate. The costs of wetland easements are obviously very site specific, and appropriate cost information should be developed for each potential acquisition of easements.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Easements are restricted in this model to wetland habitats. The purpose of the easements is to maintain wetland habitats over time.

Minimum management area. Small wetlands are generally the most likely to be drained or otherwise modified for agricultural purposes. Therefore, no minimum area for easements is specified in this model.

Model Description

Overview. This model describes the differences in selected habitat variables over time as the result of wetland easements (Table 2.4). The variables considered in this model are those that reflect the amount and distribution of cover types. Habitat variables that describe the vegetative structure of cover types are not expected to change due to easement alone. Rather, they are considered to change as the result of active management practices (such as grazing control, burning, or planting), which are not typically allowable under wetland easements. Such variables are not included in this model.

---

[1] Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

Table 2.4. Habitat variables potentially affected by wetland easements.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Number of wetlands of a specified wetland class (NW_i)	X	
Area of wetlands of a specified wetland class (AW_i)	X	
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	X	
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	X	
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of wetland easements and subsequent passive management compared to the same area without wetland easements. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

The approach recommended in this model for determining the differences in selected habitat variables due to wetland easement compared to no easements is identical to that described in the model for fee title purchase of land. That is, future conditions must be predicted for variables of interest under both a with easement and without easement scenario. Graphic presentation of the necessary comparisons were presented in Figure 2.1 (see p. 2.6). The logic and mathematical functions described in the fee title purchase model also apply to the variables considered here. In order to avoid redundancy, the logic behind the variables is not described in detail in this model. The reader is referred to the fee title purchase model for this information (see pp. 2.1-2.24).

Determination of an average annual difference in a selected variable with and without easement can be determined with three different equations. These equations require slightly different information and are presented in the same sequence for each of the variables discussed in this model. The first approach (equations labelled "a") requires an annual estimate of the variable with and without easement for each year of the period of analysis. The second approach (equations labelled "b") requires estimates for selected target years, with a minimum of two target years representing the beginning and end of the period of analysis. The third approach (equations labelled "c") requires estimates of future conditions for the without easement condition, but assumes that the with easement condition will maintain the variable at a constant level throughout the period of analysis.

Number of wetlands of a specified wetland class (NW_i). The primary purpose of wetland easements is to prevent changes in either the number or area of existing wetlands. Easements are taken on those wetlands or groups of wetlands that are anticipated to be the most likely to be adversely affected in the absence of easements. The anticipated relationship between with and without easement conditions for this variable and the following three variables is depicted in Figure 2.2b (see p. 2.13).

Equations 2.12a-c can be used to estimate the average annual difference in this variable as the result of wetland easements.

$$XNW_i = \left[\sum_{\ell=1}^{m} NWWE_{i,\ell} - \sum_{\ell=1}^{m} NWOE_{i,\ell}\right]/m \tag{2.12a}$$

$$\begin{aligned} XNW_i = {} & \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWWE_{i,2,\ell} + NWWE_{i,1,\ell})/2] \right] /m \\ & - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWOE_{i,2,\ell} + NWOE_{i,1,\ell})/2] \right] /m \end{aligned} \qquad (2.12b)$$

$$XNW_i = NW_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWOE_{i,2,\ell} + NWOE_{i,1,\ell})/2] \right] /m \qquad (2.12c)$$

where XNW_i = the average annual difference between the number of wetlands of class i with an action and the number of wetlands of class i without an action (in this case, with and without wetland easements)

$NWWE_{i,\ell}$ = the number of wetlands of class i present in year ℓ with wetland easements

$NWOE_{i,\ell}$ = the number of wetlands of class i present in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e, the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$NWWE_{i,1,\ell}$ = the number of wetlands of class i present at the beginning of time interval ℓ with wetland easements

$NWWE_{i,2,\ell}$ = the number of wetlands of class i present at the end of time interval ℓ with wetland easements

$NWOE_{i,1,\ell}$ = the number of wetlands of class i present at the beginning of time interval ℓ without wetland easements

$NWOE_{i,2,\ell}$ = the number of wetlands of class i present at the end of time interval ℓ without wetland easements

$NW_{i,B}$ = the number of wetlands of class i for a given base (e.g., baseline conditions prior to wetland easement)

Area of wetlands of a specified wetland class (AW_i). The average annual difference in this variable as the result of wetland easements can be estimated with Equations 2.13a-c.

$$XAW_i = \left[\sum_{\ell=1}^{m} AWWE_{i,\ell} - \sum_{\ell=1}^{m} AWOE_{i,\ell} \right] / m \qquad (2.13a)$$

$$XAW_i = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWWE_{i,2,\ell} + AWWE_{i,1,\ell})/2] \right] / m \qquad (2.13b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWOE_{i,2,\ell} + AWOE_{i,1,\ell})/2] \right] / m$$

$$XAW_i = AW_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWOE_{i,2,\ell} + AWOE_{i,1,\ell})/2] \right] / m \qquad (2.13c)$$

where XAW_i = the average annual difference between the area of wetlands of class i with an action and the area of wetlands of class i without an action (in this case, with and without wetland easements)

$AWWE_{i,\ell}$ = the area of wetlands of class i present in year ℓ with wetland easements

$AWOE_{i,\ell}$ = the area of wetlands of class i present in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e, the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$AWWE_{i,1,\ell}$ = the area of wetlands of class i present at the beginning of time interval ℓ with wetland easements

$AWWE_{i,2,\ell}$ = the area of wetlands of class i present at the end of time interval ℓ with wetland easements

$AWOE_{i,1,\ell}$ = the area of wetlands of class i present at the beginning of time interval ℓ without wetland easements

$AWOE_{i,2,\ell}$ = the area of wetlands of class i present at the end of time interval ℓ without wetland easements

$AW_{i,B}$ = the area of wetlands of class i for a given base (e.g., baseline conditions prior to wetland easement)

Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i). The influence of wetland easements on this variable is identical to the influence on the number of wetlands of a specified wetland class (Equations 2.12a-c) with the single exception that only those wetlands ≥0.4 ha are tallied. The average annual difference in this variable can be estimated with Equations 2.14a-c.

$$XNWL_i = \left[\sum_{\ell=1}^{m} NWLWE_{i,\ell} - \sum_{\ell=1}^{m} NWLOE_{i,\ell}\right] / m \qquad (2.14a)$$

$$XNWL_i = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLWE_{i,2,\ell} + NWLWE_{i,1,\ell})/2]\right] /m \qquad (2.14b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLOE_{i,2,\ell} + NWLOE_{i,1,\ell})/2]\right] /m$$

$$XNWL_i = NWL_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(NWLOE_{i,2,\ell} + NWLOE_{i,1,\ell})/2]\right] /m \qquad (2.14c)$$

where $XNWL_i$ = the average annual difference between the number of wetlands ≥0.4 ha of class i with an action and the number of wetlands of class i without an action (in this case, with and without wetland easements)

$NWLWE_{i,\ell}$ = the number of wetlands ≥0.4 ha of class i present in year ℓ with wetland easements

$NWLOE_{i,\ell}$ = the number of wetlands ≥0.4 ha of class i present in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e, the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$NWLWE_{i,1,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ with wetland easements

$NWLWE_{i,2,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the end of time interval ℓ with wetland easements

$NWLOE_{i,1,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ without wetland easements

$NWLOE_{i,2,\ell}$ = the number of wetlands ≥0.4 ha of class i present at the end of time interval ℓ without wetland easements

$NWL_{i,B}$ = the number of wetlands ≥0.4 ha of class i for a given base (e.g., baseline conditions prior to wetland easement)

Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i). The influence of wetland easements on this variable is identical to the influence on the area of wetlands of a specified wetland class (Equations 2.13 a-c) with the single exception that only those wetlands ≥0.4 ha are considered. The average annual difference in this variable can be estimated with Equations 2.15a-c.

$$XAWL_i = \left[\sum_{\ell=1}^{m} AWLWE_{i,\ell} - \sum_{\ell=1}^{m} AWLOE_{i,\ell} \right] /m \qquad (2.15a)$$

$$XAWL_i = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{i,\ell}) \times [(AWLWE_{i,2,\ell} + AWLWE_{i,1,\ell})/2] \right] /m \qquad (2.15b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWLOE_{i,2,\ell} + AWLOE_{i,1,\ell})/2] \right] /m$$

$$XAWL_i = AWL_{i,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(AWLOE_{i,2,\ell} + AWLOE_{i,1,\ell})/2] \right] /m \qquad (2.15c)$$

where $XAWL_i$ = the average annual difference between the area of wetlands ≥0.4 ha of class i with an action and the area of wetlands ≥0.4 ha of class i without an action (in this case, with and without wetland easements)

$AWLWE_{i,\ell}$ = the area of wetlands ≥0.4 ha of class i present in year ℓ with wetland easements

$AWLOE_{i,\ell}$ = the area of wetlands ≥0.4 ha of class i present in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e, the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$AWLWE_{i,1,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ with wetland easements

$AWLWE_{i,2,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the end of time interval ℓ with wetland easements

$AWLOE_{i,1,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the beginning of time interval ℓ without wetland easements

$AWLOE_{i,2,\ell}$ = the area of wetlands ≥0.4 ha of class i present at the end of time interval ℓ without wetland easements

$AWL_{i,B}$ = the area of wetlands ≥0.4 ha of class i for a given base (e.g., baseline conditions prior to wetland easement)

Area of specified nonwetland cover type (ACT_j). The area of certain cover types may be expected to increase over time without wetland easements. Specifically, this applies to those cover types created in place of drained wetlands, such as cropland and tame grassland. This relationship is depicted in Figure 2.2b (p. 2.13). The average annual difference in this variable due to wetland easements can be estimated with Equations 2.16a-c.

$$XACT_j = \left[\sum_{\ell=1}^{m} ACTWE_{j,\ell} - \sum_{\ell=1}^{m} ACTOE_{j,\ell} \right] / m \qquad (2.16a)$$

$$XACT_j = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTWE_{j,2,\ell} + ACTWE_{j,1,\ell})/2] \right] / m \qquad (2.16b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTOE_{j,2,\ell} + ACTOE_{j,1,\ell})/2] \right] / m$$

$$XACT_j = ACT_{j,B} - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(ACTOE_{j,2,\ell} + ACTOE_{j,1,\ell})/2] \right] / m \qquad (2.16c)$$

where $XACT_j$ = the average annual difference between the area of cover type j with an action and the area of cover type j without an action (in this case, with and without wetland easements)

$ACTWE_{j,\ell}$ = the area of cover type j present in year ℓ with wetland easements

$ACTOE_{j,\ell}$ = the area of cover type j present in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e, the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$ACTWE_{j,1,\ell}$ = the area of cover type j present at the beginning of time interval ℓ with wetland easements

$ACTWE_{j,2,\ell}$ = the area of cover type j present at the end of time interval ℓ with wetland easements

$ACTOE_{j,1,\ell}$ = the area of cover type j present at the beginning of time interval ℓ without wetland easements

$ACTOE_{j,2,\ell}$ = the area of cover type j present at the end of time interval ℓ without wetland easements

$ACT_{j,B}$ = the area of cover type j for a given base (e.g., baseline conditions prior to wetland easement)

Percent of area in cropland (PC). The proportion of an area in cropland will likely increase over time without wetland easements as the result of wetland draining for agricultural purposes (as depicted in Figure 2.2a, p. 2.13). The average annual difference in this variable due to wetland easements can be estimated with Equations 2.17a-c.

$$XPC = \left[\sum_{\ell=1}^{m} PCWE_{\ell} - \sum_{\ell=1}^{m} PCOE_{\ell} \right] / m \tag{2.17a}$$

$$XPC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCWE_{2,\ell} + PCWE_{1,\ell})/2] \right] /m \tag{2.17b}$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCOE_{2,\ell} + PCOE_{1,\ell})/2] \right] /m$$

$$XPC = PC_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PCOE_{2,\ell} + PCOE_{1,\ell})/2] \right] /m \tag{2.17c}$$

where XPC = the average annual difference between the proportion of an area in cropland with an action and the proportion of an area in cropland without an action (in this case, with and without wetland easement)

$PCWE_{\ell}$ = the proportion of an area in cropland in year ℓ with wetland easement

$PCOE_{\ell}$ = the proportion of an area in cropland in year ℓ without wetland easement

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PCWE_{1,\ell}$ = the proportion of an area in cropland at the beginning of time interval ℓ with wetland easement

$PCWE_{2,\ell}$ = the proportion of an area in cropland at the end of time interval ℓ with wetland easement

$PCOE_{1,\ell}$ = the proportion of an area in cropland at the beginning of time interval ℓ without wetland easement

$PCOE_{2,\ell}$ = the proportion of an area in cropland at the end of time interval ℓ without wetland easement

PC_B = the proportion of area in cropland for a given base (e.g., baseline conditions prior to wetland easement)

Percent of area in pasture/hayland (PPH). The amount of an area in pasture/hayland may increase over time without easements if wetlands are drained and converted to land uses of grazing or mowing. Easements will therefore result in a net negative difference in the level of this variable. The net difference in this variable due to wetland easement can be estimated with Equations 2.18a-c.

$$XPPH = \left[\sum_{\ell=1}^{m} PPHWE_{\ell} - \sum_{\ell=1}^{m} PPHOE_{\ell} \right] /m \qquad (2.18a)$$

$$XPPH = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHWE_{2,\ell} + PPHWE_{1,\ell})/2] \right] /m \qquad (2.18b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHOE_{2,\ell} + PPHOE_{1,\ell})/2] \right] /m$$

$$XPPH = PPH_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PPHOE_{2,\ell} + PPHOE_{1,\ell})/2] \right] /m \qquad (2.18c)$$

where $XPPH$ = the average annual difference between the proportion of an area in pasture/hayland land uses with an action and the proportion of an area in pasture/hayland land uses without an action (in this case, with and without easements)

$PPHWE_\ell$ = the proportion of an area in pasture/hayland land uses in year ℓ with wetland easements

$PPHOE_\ell$ = the proportion of an area in pasture/hayland land uses in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PPHWE_{1,\ell}$ = the proportion of an area in pasture/hayland land uses at the beginning of time interval ℓ with wetland easements

$PPHWE_{2,\ell}$ = the proportion of an area in pasture/hayland land uses at the end of time interval ℓ with wetland easements

$PPHOE_{1,\ell}$ = the proportion of an area in pasture/hayland land uses at the beginning of time interval ℓ without wetland easements

$PPHOE_{2,\ell}$ = the proportion of an area in pasture/hayland land uses at the end of time interval ℓ without wetland easements

PPH_B = the proportion of an area in pasture/hayland land uses for a given base (e.g., baseline conditions prior to wetland easements)

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types, including tame grassland, native grassland, shrubland, and woodland. If it is assumed that the area in crops or pasture/hayland will increase over time without easement, then the amount of idle land can be expected to decrease over time without easement. Future conditions without easements may be increased (or continued) conversion of wetlands and associated idle cover to agricultural uses. Therefore, easements may result in a greater amount of idle land available over time compared to the same land without easement for wildlife management purposes (Figure 2.2b). The average annual difference in this variable between with easement and without easement conditions can be estimated with: (1) Equation 2.19a, which requires annual estimates of the variable; (2) Equation 2.19b, which requires estimates for selected target years; and (3) Equation 2.19c, which also uses target year estimates, but with the assumption of no change in the variable over time with land purchase.

$$XPIL = \left[\sum_{\ell=1}^{m} PILWE_{\ell} - \sum_{\ell=1}^{m} PILOE_{\ell} \right] / m \qquad (2.19a)$$

$$XPIL = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILWE_{2,\ell} + PILWE_{1,\ell})/2] \right] / m$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILOE_{2,\ell} + PILOE_{1,\ell})/2] \right] / m \qquad (2.19b)$$

$$XPIL = PIL_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(PILOE_{2,\ell} + PILOE_{1,\ell})/2] \right] / m \qquad (2.19c)$$

where XPIL = the average annual difference between the percent of an area in idle land with an action and the percent of an area in idle land without an action (in this case, with and without easement)

$PILWE_{\ell}$ = the percent of an area in idle land in year ℓ with wetland easement

$PILOE_{\ell}$ = the percent of an area in idle land in year ℓ without wetland easement

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PILWE_{1,\ell}$ = the percent of an area in idle land at the beginning of time interval ℓ with wetland easements

$PILWE_{2,\ell}$ = the percent of an area in idle land at the end of time interval ℓ with wetland easements

$PILOE_{1,\ell}$ = the percent of an area in idle land at the beginning of time interval ℓ without wetland easements

$PILOE_{2,\ell}$ = the percent of an area in idle land at the end of time interval ℓ without wetland easements

PIL_B = the percent of an area in idle land for a given base (e.g., baseline conditions prior to wetland easements)

Future conditions can best be estimated based on current and projected land use trends. For example, if idle land in a given area has been decreasing at a known rate, then that rate may be applied to determine the proportion of idle land present at any point during the period of analysis.

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km² sample area that contain or border idle habitat, defined as habitat that is not grazed or hayed, or does not support crops. Wetland easements without additional active management will most likely maintain this variable at a constant level equal to that existing at the time of the easements. However, without easements it is likely that the number of 4-ha cells/2.59 km² with idle cover will decrease as the result of increased (or continued) conversion of wetlands and associated idle cover to agricultural uses (as depicted in Figure 2.2b). The effect of wetland easements on this variable is a potentially greater distribution of idle cover available over time than without easements. This difference can be estimated with: (1) Equation 2.20a, which requires annual estimates of the variable; (2) Equation 2.20b, which requires estimates for selected target years; and (3) Equation 2.20c, which also uses target year estimates, but with the assumption of no change in the variable over time with wetland easements.

$$XDIC = \left[\sum_{\ell=1}^{m} DICWE_{\ell} - \sum_{\ell=1}^{m} DICOE_{\ell}\right]/m \qquad (2.20a)$$

$$XDIC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICWE_{2,\ell} + DICWE_{1,\ell})/2]\right]/m \qquad (2.20b)$$

$$- \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICOE_{2,\ell} + DICOE_{1,\ell})/2]\right]/m$$

$$XDIC = DIC_B - \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(DICOE_{2,\ell} + DICOE_{1,\ell})/2] \right] /m \qquad (2.20c)$$

where $XDIC$ = the average annual difference between the distribution of idle cover with an action and the distribution of idle cover without an action (in this case, with and without easements)

$DICWE_\ell$ = the distribution of idle cover in year ℓ with wetland easements

$DICOE_\ell$ = the distribution of idle cover in year ℓ without wetland easements

m = the period of analysis, i.e., the life of the project

t = the number of time intervals being evaluated, i.e., the number of target years minus one

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$DICWE_{1,\ell}$ = the distribution of idle cover at the beginning of time interval ℓ with wetland easements

$DICWE_{2,\ell}$ = the distribution of idle cover at the end of time interval ℓ with wetland easements

$DICOE_{1,\ell}$ = the distribution of idle cover at the beginning of time interval ℓ without wetland easements

$DICOE_{2,\ell}$ = the distribution of idle cover at the end of time interval ℓ without wetland easements

DIC_B = the distribution of idle cover for a given base (e.g., baseline conditions prior to wetland easements)

The most accurate way of measuring the distribution of idle cover in future years without wetland easements (i.e., $DICOE_\ell$) is to use a grid overlay on a map of projected cover types. A simpler means of estimating the distribution of idle cover is to decrease the variable by the same proportion that the area of idle cover is decreased (i.e., the increased amount of area converted to cropland or pasture/hayland at year ℓ). For example, if the area of cropland and pasture/hayland at year ℓ has increased from baseline conditions by 15%, then the distribution of idle cover can be decreased by 15% from the baseline distribution. This relationship is expressed mathematically in Equation 2.21.

$$DICOE_{\ell} = DIC_B - \left[\frac{(ACOE_{\ell} + APHOE_{\ell}) - (AC_B + APH_B)}{\text{Total study area}} \times DIC_B \right] \qquad (2.21)$$

where $DICOE_{\ell}$ = the distribution of idle cover in year ℓ without wetland easements

DIC_B = the distribution of idle cover for a given base (e.g., baseline conditions prior to wetland easements)

$ACOE_{\ell}$ = the area of cropland at year ℓ without wetland easements

$APHOE_{\ell}$ = the area of pasture/hayland at year ℓ without wetland easements

AC_B = the area of cropland at baseline conditions

APH_B = the area of pasture/hayland at baseline conditions

Model Relationships

The presumed relationships between wetland easements and a number of habitat variables were described in the preceding section. The primary influence of wetland easements is assumed to be on absolute or relative area of cover types or land uses. Habitat variables describing the physical characteristics of vegetation (e.g., herbaceous canopy cover or grass height) are not considered to be directly influenced by wetland easements.

Table 2.5 presents a summary of the variables included in this model and a reference to the equations that are used to estimate the influence of wetland easements on the selected variables.

Application of the Model

This model can be used to evaluate the influence of wetland easements on selected variables describing available habitat. The model can be used in management gaming or in the evaluation of mitigation or management plans. The effects of wetland easements on habitat variables can only be determined by comparing future conditions for an area with and without wetland easements. Such projections of land use and cover type changes should consider current or historical trends and are obviously site-specific.

Table 2.5. A summary of the habitat variables potentially affected by wetland easements.

Variable (acronym)	Equation	Page(s)
Number of wetlands of a specified wetland class (NW_i)	2.12a-c	2.28-2.29
Area of wetlands of a specified wetland class (AW_i)	2.13a-c	2.30
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	2.14a-c	2.31
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	2.15a-c	2.32-2.33
Area of specified nonwetland cover type (ACT_j)	2.16a-c	2.34
Percent of area in cropland (PC)	2.17a-c	2.35
Percent of the area in pasture/hayland (PPH)	2.18a-c	2.36-2.37
Percent of area in idle land (PIL)	2.19a-c	2.38
Distribution of idle cover (DIC)	2.20a-c	2.39-2.40

Information that must be provided by a model user before using the equations in this model is as follows.

1. Baseline conditions for all variables considered in this model (Table 2.5).

2. Area of each cover type under conditions of with and without wetland easements either for each year of the period of analysis, or for selected target years.

3. Number and area of wetlands, by wetland class, under conditions of with and without wetland easements either for each year of the period of analysis, or for selected target years. This information is needed by wetland class for all wetlands and for wetlands ≥0.4 ha.

4. Total area in pasture or hayland land uses under conditions of with and without wetland easements either for each year of the period of analysis, or for selected target years.

5. Total area that is not in crops, hayed, or grazed by domestic livestock under conditions of with and without wetland easements either for each year of the period of analysis, or for selected target years.

3. UPLAND VEGETATION DEVELOPMENT

a. Plant dense nesting cover

MANAGEMENT ACTION INFORMATION

Purpose

Planting dense nesting cover consists of planting introduced cool-season grasses and legumes for the primary purpose of providing "...attractive and secure nesting cover for dabbling ducks" (Klett et al. 1984:134). However, alteration of the habitat by planting will also impact other wildlife species inhabiting grasslands. The primary differences between this action and seeding native grasses are the species of plants used and subsequent maintenance activities.

Effects of Management Action

The direct effect of planting introduced cool-season grasses and legumes is to change from one cover type (i.e., the cover type existing prior to planting) to another (i.e., nonnative grassland). Individual habitat variables will change over time in the newly created cover type, but these changes are a function of the cover type itself rather than a function of how much area is planted in dense nesting cover.

Several investigators (summarized by Lokemoen 1984) have found greater numbers of ducks fledged in fields of introduced grass-legume cover than on unmanaged farmlands. Initiation rates of waterfowl nests in introduced grass-legume habitats averaged 91/km^2 in South Dakota and 101/km^2 in North Dakota (Klett et al. 1984). Initiation rates were similar to or less than rates in seeded native grasses and greater than rates in native prairie. Kirsch et al. (1978) emphasized the importance of dense residual vegetation (i.e., available prior to new year's growth) from the previous growing season in nest establishment by waterfowl. Residual vegetation may also be important to other grassland nesting species, such as the sharp-tailed grouse (Kohn et al. 1982; Kirsch, pers. comm.).

Maintenance and Management

Establishment and maintenance of introduced cool-season grasses and legumes includes the activities of seeding, periodic spraying, and replacement (Lokemoen 1984). Seeded introduced cover is considered a semipermanent cover that requires periodic rejuvenation (Duebbert et al. 1981; Lokemoen 1984) "... because plant vigor declines with time" (Lokemoen 1984:585).

A variety of species have been recommended for establishing introduced cover. Klett et al. (1984) studied introduced cover consisting of intermediate wheatgrass (Agropyron intermedium), tall wheatgrass (A. elongatum), crested wheatgrass (A. cristatum), quackgrass (A. repens), smooth brome (Bromus inermis), Kentucky bluegrass (Poa pratensis), sweetclover (Melilotus spp.), and alfalfa (Medicago sativa). Lokemoen (1984) studied the cost-effectiveness (in terms of cost per fledged duck) of planting introduced cover, consisting of smooth brome, intermediate wheatgrass, alfalfa, and sweetclover. Duebbert et al. (1981) provided guidance for establishing introduced cool-season grasses consisting of tall wheatgrass, intermediate wheatgrass, alfalfa, and sweetclover.

The decision to plant introduced cover or native grasses should be based on site quality and climate (Klett et al. 1984). Areas that receive <40 cm of annual precipitation are most suited for introduced grasses and legumes (Duebbert et al. 1981; Klett et al. 1984). Mechanical tillage is the recommended method of rejuvenation of introduced cool-season grasses and legumes, and sites selected for this type of planting should be suitable for cultivation (Duebbert et al. 1981). Duebbert et al. (1981) recommended a planting rate of 12.4 pounds of bulk seed per acre, which yields 10.0 pounds of pure live seed per acre. Additional guidance on planting cool-season grasses and legumes in the Prairie Pothole region is provided in Duebbert et al. (1981).

Seeded grasslands require annual maintenance in order to become established. Most failures in establishing seeded grasslands are due to inadequate suppression of weeds (Duebbert et al. 1981). Weed spraying is the primary annual maintenance activity considered in evaluating the cost-effectiveness of planting introduced grasses and legumes (Lokemoen 1984).

Introduced cool-season grasses and legumes must be rejuvenated periodically in order to maintain stand vigor. The frequency of rejuvenation varies by site, establishment success, soil fertility, moisture, species composition, and other factors (Duebbert et al. 1981). The recommended frequency is 5 to 10 years although "...it is not possible to prescribe exact schedules" (Duebbert et al. 1981:19). Lokemoen (1984) assumed a management life of 10 years for introduced cool-season grasses and legumes; i.e., the practice must be repeated every 10 years during the period of analysis.

Labor and Materials

The cost of establishing introduced cool-season grasses and legumes includes development, maintenance, and replacement costs. Development costs include materials (seeds), tillage, packing, and seeding (Lokemoen 1984). Maintenance costs include the labor, transportation, and materials involved in spraying weeds. Lokemoen (1984) presented cost information for establishing 1 acre of introduced cool-season grasses and legumes. Annual development costs were estimated to be $15.11/acre if a cooperating farmer does the site preparation, packing, and seeding in exchange for 2 years of free use of the lands, and $44.18/acre if a manager does all establishment work without a cooperating farmer. Annual maintenance costs were estimated to be $0.63/acre. These costs are summarized in Table 3.1. Costs of establishing introduced cool-season grasses and legumes were also estimated for the Garrison Diversion Unit study. The total discounted cost (at 3-1/8%) was estimated to be $50.75/acre for the initial 10-year cycle and $37.59/acre for each subsequent 10-year cycle, with the difference attributable to fertilization during the first cycle only. The itemized costs involved in these estimates are provided in Table 3.2.

Table 3.1. Cost categories and estimated costs for planting introduced grass-legume cover in the Dakota pothole region (from Lokemoen 1984).

Materials and maintenance	Cost
Materials (per acre)	
Tall wheatgrass (4.5 pounds pure live seed)	$ 5.18
Intermediate wheatgrass (4.0)	6.00
Alfalfa (1.0)	1.25
Sweetclover (0.5)	0.16
Total	12.59
Correction factor[a] (20% of materials)	2.52
Total materials cost	$15.11
Maintenance (per acre)	
Labor (0.5 hrs)	$ 0.32
Transportation (0.625 mi)	0.21
Spraying (0.025 ac)	0.10
Total annual maintenance cost	$ 0.63

[a] Materials cost increased 20% because cover is not available during the 2-year seeding period.

05

Table 3.2. Cost categories and estimated costs for planting dense nesting cover in North Dakota.[a]

Year	Activity	Cost/acre[b]
1	Fallow (tillage cost offset by nursery crop)	$ 0
2	Seedbed preparation, seed, and seeding	19.00
	Fertilization	14.00
	Initial herbicide spraying	7.00
3	Reseeding (20% of area)	8.00
	Follow-up herbicide spraying (15% of area)	0.83
4-10	Herbicide spraying (10% annually)	0.90

Cost of subsequent cycles includes all categories and costs of the first cycle except for fertilization.

---

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

[b] These costs are not summed to a single total because the activities occur in different years. An appropriate discount factor based on a selected discount rate must be used to determine the present worth of each activity. For the Garrison Diversion Unit study, the discounted cost was estimated to be $50.75/acre for the first 10-year cycle and $37.59/acre for subsequent 10-year cycles, based on a discount rate of 3-1/8%.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Establishment of introduced cool-season grasses and legumes can theoretically be accomplished on any upland type that is suitable for cultivation. In practice, however, such management may best be done on croplands or other lands without native vegetation due to farming activities. Duebbert et al. (1981) recommended that all native prairies on wildlife management areas should be maintained in their native condition. For purposes of this model, it is assumed that the establishment of dense nesting cover is restricted to existing croplands.

Minimum management area. It is theoretically possible, although not necessarily practical, to plant any size area to dense nesting cover. However, there are practical limits in terms of cost-effectiveness as to the minimum area that should be considered for planting dense nesting cover. Cost information (Lokemoen 1984) and planting guidelines (Duebbert et al. 1981) are typically presented on the basis of 1.0 acre; therefore, 1.0 acre is assumed to be the minimum practical area potentially planted to dense nesting cover.

Model Description

Overview. This model describes the relationships between the action of planting dense nesting cover and selected habitat variables (Table 3.3). The variables that are expected to change as a result of different amounts of planted dense nesting cover are those that reflect the amount and distribution of cover types. Structural habitat variables within planted dense nesting cover will change over time, but not in response to the amount of dense nesting cover planted. Average annual values for such variables must be estimated in order to determine average annual Habitat Units for a given species. This can be done by estimating values for each variable at selected target years over the life of the management action. Lokemoen (1984) recommended a life of 10 years for planted dense nesting cover. Duebbert et al. (1981) recommended that planted dense nesting cover must be rejuvenated by tillage and replanting every 5 to 10 years. A study of the Garrison Diversion Unit project assumed a life of 7 years for dense nesting cover with an initial 3 years of site preparation and planting. The actual life will vary by site and should be determined by users.

In order to determine impacts of planting dense nesting cover on the six wildlife species identified in the Introduction, average annual values must be estimated for the following variables over the assumed life of the planted cover: (1) average visual obstruction measurement, (2) percent herbaceous canopy cover, (3) proportion of herbaceous canopy that is grass, and (4) maximum height of grass canopy.

Area of specified nonwetland cover type (ACT_j). Planting dense nesting cover involves the change of one nonwetland cover type to another. In most situations, the creation of the tame grassland cover type that results from planting dense nesting cover is done at the expense of cropland. The effect of planting dense nesting cover is to increment the area of tame grassland by the amount of dense nesting cover planted and to decrement the area of cropland by a similar amount. Although it is technically feasible to convert cover types other than cropland to tame grassland, it is assumed in this model that cropland will be the only available host cover type for planting dense nesting cover due to the value of other native cover types. For example, Duebbert et al. (1981) recommended that all native prairies should be preserved on areas intended for wildlife management. The change in area for tame grassland and cropland cover types are expressed in Equations 3.1 and 3.2, respectively.

Table 3.3. Habitat variables potentially affected by planting dense nesting cover.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)	X	X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	
Distance to a wetland ≥0.4 ha (DW)	X	X

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of planting dense nesting cover. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

$$ACT_1 = ACT_{1B} + ANC \qquad (3.1)$$

where ACT_1 = the area of tame grassland (nonwetland cover type 1) following a management action

ACT_{1B} = the area of tame grassland (nonwetland cover type 1) prior to management

ANC = the area of dense nesting cover planted

$$ACT_3 = ACT_{3B} - ANC \qquad (3.2)$$

where ACT_3 = the area of cropland (nonwetland cover type 3) following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ANC = the area of dense nesting cover planted (based on the assumption that all planting of dense nesting cover will be done in existing croplands)

Percent of an area in cropland (PC). As discussed above, it is assumed in this model that all planted dense nesting cover will be done in existing cropland. The effect of planting dense nesting cover is to reduce the area of cropland and, therefore, the proportion of an area in cropland. This simple relationship is expressed in Equation 3.3.

$$PC = \left[\frac{ACT_{3B} - ANC}{\text{Total study area}}\right] \times 100 \qquad (3.3)$$

where PC = the percent of an area in cropland following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ANC = the area of dense nesting cover planted (based on the assumption that all planting of dense nesting cover will be done in existing croplands)

Percent of cropland cover type in corn or grain crops (PCG). Planting dense nesting cover in cropland may cause a positive, neutral, or negative change in the proportion of cropland in corn or other grain crops. If dense nesting cover is assumed to be planted in different crop types in the same proportion as the different crop types occur, then the impact on this variable will be neutral (note, however, that the absolute area of cropland will decrease in this situation, according to Equation 3.2). If the preceding assumption is invalid, then the effect on the variable can be positive or negative depending on the distribution of the planted cover. The value of this variable following planting of dense nesting cover can be determined with Equation 3.4.

$$PCG = \left[\frac{ACG_B - ANCCG}{ACT_{3B} - ANC} \right] \times 100 \qquad (3.4)$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn or other grain crops prior to management

$ANCCG$ = the area of dense nesting cover planted in cropland producing corn or other grain crops

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ANC = the area of dense nesting cover planted (based on the assumption that all planting of dense nesting cover will be done in existing croplands)

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. Planting of dense nesting cover in cropland will increase the area of idle land if the tame grassland is neither hayed nor grazed. Duebbert et al. (1981) recommended that grasslands managed for wildlife should not have annual grazing or mowing. It is assumed that planted tame grassland will not be mowed or grazed and that it will, therefore, meet the definition of idle land. The effect of planting dense nesting cover on the area of idle land is to simply increase the area of idle land by the area of dense nesting cover planted. Equation 3.5 presents this relationship with idle land expressed as a proportion of a study area.

$$PIL = \left[\frac{AIL_B + ANC}{\text{Total study area}} \right] \times 100 \qquad (3.5)$$

where PIL = the percent of an area in idle land

AIL_B = the area of idle land prior to management

ANC = the area of dense nesting cover planted (based on the assumptions that all planting of dense nesting cover will be done in existing croplands and that the planted cover will be neither grazed nor mowed)

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km^2 sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed, and do not support crops. The absolute amount of idle cover within each 4-ha cell is not considered in calculating this variable. If it is assumed that tame grassland is created in existing cropland, and that the tame grassland is not hayed or grazed (i.e., it is idle cover), then every 4 ha of cropland converted to tame grassland increases the number of idle 4-ha square grids by one. However, this is a conservative estimate, since a grid is also included as an idle grid if it borders idle cover in an adjacent grid. If only 4 ha of cropland is converted to grassland, then three to five grids may be changed to an idle classification (Figure 3.1). Several grids may also be changed to an idle classification even if <4 ha of cropland is converted to grassland, depending on the distribution of the planted cover. The amount and distribution of cropland converted to tame grassland (e.g., whether one contiguous block or scattered smaller blocks of cropland are planted to dense nesting cover) will determine the ratio between area of cropland converted to tame grassland and the increase in the number of grids classified as idle. Hypothetical applications of this management action on a study area map can be used to determine the actual ratio between area converted to tame grassland and number of idle grid cells. Equation 3.6 presents the simplest, most conservative, case where each 4 ha converted to tame grassland increases the number of grid cells with idle cover by one. Equation 3.6 produces an output in terms of number of grid cells per 2.59 km^2. Users may wish to change the denominator to the ANC term (i.e., 4) to more accurately reflect the expected ratio of planted hectares to idle grid cells.

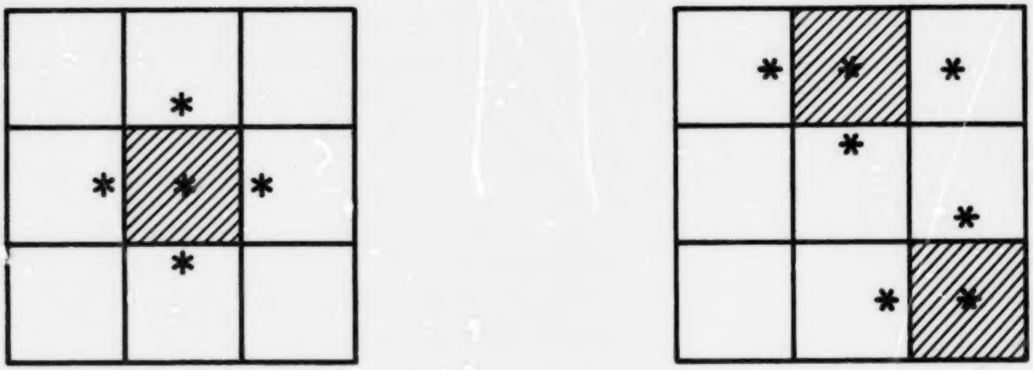


Figure 3.1. Examples of how the distribution of planted dense nesting cover changes the ratio of planted cover area to number of idle grid cells (shaded grid cells = 4 ha of planted cover, * indicates blocks classified as idle cover as a result. Based on assumption that adjacent grids are not classified as idle prior to planting).

$$DIC = NGIL_B + \left[\frac{ANC}{4} \times \frac{259}{\text{Total study area (ha)}}\right] \qquad (3.6)$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

$NGIL_B$ = the number of 4-ha grid cells per 2.59 km² that contain or border idle cover prior to management

ANC = the area (ha) of dense nesting cover planted (based on the assumptions that all planting of dense nesting cover will be done in existing croplands and the planted cover will be neither grazed nor mowed)

Distance to wetland ≥0.4 ha (DW). Planting dense nesting cover may decrease or increase the average distance from tame grassland to a wetland ≥0.4 ha, depending on where the planting is done. For example, if dense nesting cover is planted greater than the average distance from existing tame grassland to a wetland ≥0.4 ha, then the average distance from tame grassland will increase. An estimate of this variable can be made by determining a weighted (by area) average distance from existing tame grassland and from created tame grassland (Equation 3.7). If no tame grassland exists prior to management, then the distance to wetland from any created tame grassland is the same as for the host cover type (i.e., cropland, assuming that cropland is the only cover type that can be planted to dense nesting cover).

$$DW_1 = \frac{(DW_{1B} \times ACT_{1B}) + (DW_{3B} \times ANC)}{ACT_{1B} + ANC} \qquad (3.7)$$

where DW_1 = the distance to a wetland ≥0.4 ha from tame grassland (nonwetland cover type 1) following a management action

DW_{1B} = the distance to a wetland ≥0.4 ha from tame grassland (nonwetland cover type 1) prior to management

ACT_{1B} = the area of tame grassland (nonwetland cover type 1) present prior to management

DW_{3B} = the distance to a wetland ≥0.4 ha from cropland (nonwetland cover type 3) prior to management

ANC = the area of dense nesting cover planted (based on the assumption that all planting of dense nesting cover will be done in existing croplands)

Model Relationships

The presumed relationships between planting dense nesting cover and a number of habitat variables were described in the preceding section. Table 3.4 presents a summary of the variables discussed in this model and a reference to the equation where each relationship is presented.

Table 3.4. A summary of the habitat variables potentially affected by planting dense nesting cover.

Variable (acronym)	Equation(s)	Page
Area of specified nonwetland cover type (ACT_j)	3.1, 3.2	3.6-3.7
Percent of area in cropland (PC)	3.3	3.7
Percent of cropland cover type in corn or other grain crops (PCG)	3.4	3.8
Percent of area in idle land (PIL)	3.5	3.8
Distribution of idle cover (DIC)	3.6	3.10
Distance to wetland ≥0.4 ha (DW)	3.7	3.10

064

Application of the Model

This model can be used to evaluate the influence of planting dense nesting cover on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the model user must provide site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all habitat variables.
2. The area of cropland and tame grassland at initial conditions, and the total area of all cover types.
3. An estimate of the ratio between the area of cropland planted to dense nesting cover and the number of grid cells that will contain or border idle cover as a result. This ratio can be estimated by assuming a fixed, site-specific pattern of planting.

LITERATURE CITED

Duebbert, H.F., E.T. Jacobson, K.F. Higgins, and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the Prairie Pothole region. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. No. 234. 21 pp.

Kirsch, L.M., H.F. Duebbert, and A.D. Kruse. 1978. Grazing and haying effects on habitat of upland nesting birds. Trans. N. Am. Wildl. Nat. Resour. Conf. 43:486-497.

Klett, A.T., H.F. Duebbert, and G.L. Heismeyer. 1984. Use of seeded native grasses as nesting cover by ducks. Wildl. Soc. Bull. 12(2):134-138.

Kohn, S.C., R.L. Linder, and G.D. Kobriger. 1982. Sharp-tailed grouse nesting habitat in southwestern North Dakota. Proc. Wildlife-Livestock Relationships Symp. 10:166-174.

Lokemoen, J.T. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

3. UPLAND VEGETATION DEVELOPMENT

b. Plant native grasses

MANAGEMENT ACTION INFORMATION

Purpose

Planting native grasses consists of seeding a mixture of warm-season grasses, including big bluestem (*Andropogon geradii*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*) (Duebbert et al. 1981; Lokemoen 1984). Planting native grasses is a management option on upland habitats "...to provide attractive and secure nesting cover for dabbling ducks" (Klett et al. 1984:134). The primary differences between this action and planting introduced cool-season grasses and legumes (i.e., dense nesting cover) are the species of plants used and subsequent maintenance activities.

Effects of Management Action

The direct effect of planting native grasses is to change from one cover type (i.e., the cover type existing prior to planting) to another (i.e., planted native grassland). Individual habitat variables will change over time in the newly created cover type, but these changes are a function of the cover type itself rather than a function of how much area is planted with native grasses.

Big bluestem, Indiangrass, and switchgrass are resistant to flattening by snow and are, therefore, able to provide tall and dense cover prior to new spring growth (Duebbert et al. 1981). Kirsch et al. (1978) emphasized the importance of this dense residual vegetation from the previous growing season in nest establishment by waterfowl. Residual vegetation may also be important to other grassland nesting species, such as the sharp-tailed grouse (Kohn et al. 1982; Kirsch pers. comm.). Published information on the production of fledged ducks in seeded native grass cover is limited, but production appears to be approximately one-half that of planted introduced grass-legume cover (Lokemoen 1984). Klett et al. (1984) reported higher waterfowl nest initiation rates where seeded natives were dominant or codominant (149/km^2 in South Dakota; 128/km^2 in North Dakota) than in seeded introduced grasses (91/km^2 in South Dakota; 101/km^2 in North Dakota) or unplowed native prairie (76/km^2 in South Dakota; 29/km^2 in North Dakota). Nest success in seeded native grass cover was not significantly different from that in seeded introduced grasses or native prairie. The best nesting habitat for upland sandpiper (*Bartramia longicauda*) was native grassland (Kirsch and Higgins 1976).

Maintenance and Management

Seeded native grasses can be considered permanent cover; in contrast, seeded introduced grasses and legumes must be periodically replanted (Duebbert et al. 1981). Lokemoen (1984) considered planted native grass cover to have an effective life of 50 years; this life was selected on the basis of a reasonable maximum planning period rather than on the need for replanting native cover.

The decision to plant native grasses or introduced cover should be based on site quality and climate (Klett et al. 1984). Areas that receive ≥50 cm of precipitation are most suited for establishment of the native grasses listed above (Duebbert et al. 1981; Klett et al. 1984). Other native grasses, such as green needlegrass (Stipa viridula) and western wheatgrass (Agropyron smithii), can be established in areas with <50 cm annual precipitation (Klett et al. 1984). Introduced cool-season grasses and legumes are best suited for areas with ≤40 cm annual precipitation (Duebbert et al. 1981; Klett et al. 1984). Duebbert et al. (1981:10) advise that "soils on which tall, warm-season native grasses grow best are moderately deep to deep, well-drained, and medium to moderately fine textured."

Stands of seeded native grasses are generally more difficult to establish than introduced grasses and legumes, but do not require periodic replacement through tillage and reseeding as do stands of introduced cover (Duebbert et al. 1981; Lokemoen 1984). Duebbert et al. (1981) recommended a planting rate of 20.5 pounds of bulk seed per acre, which yields 9.2 pounds of pure live seed per acre, in order to establish tall, warm-season native grasses. Prescribed burning and planned grazing are potential management actions to maintain planted native grass cover in optimum condition, although annual grazing or mowing is not recommended (Duebbert et al. 1981). Lokemoen (1984:591) described maintenance activities as "...weed spraying on 5% of the acres annually and a cover maintenance burn every 5 years."

Detailed guidance in establishing both native grasses and introduced grasses and legumes is provided by Duebbert et al. (1981), and includes information on site and seedbed preparation, planting equipment and methods, rates and dates of seeding, seed sources, and methods of rejuvenation.

Labor and Material

The costs of establishing tall, warm-season native grasses include development and maintenance costs. Planting native grasses is considered to yield permanent cover that does not need replacement, so replacement costs are not considered in this management action.

Development costs include materials (seeds), ground preparation, weed removal, and seeding (Lokemoen 1984). Costs can be reduced by having a cooperating farmer do the development work in exchange for free use of the land for 3 years. Maintenance costs include the labor, transportation, and materials involved in spraying weeds and burning every 5 years. Estimated establishment cost equalled $43.06/acre (presuming the cooperating farmer approach) and annual maintenance costs equalled $1.44/acre (Lokemoen 1984). These costs are summarized in Table 3.5. Costs of establishing tall, warm-season native grasses were also estimated for the Garrison Diversion Unit study. Development costs included tillage in year 1; materials, seedbed preparation, seeding, fertilizing, and an initial herbicide spraying in year 2; and reseeding 20% of the planted area and a followup spraying of 15% of the area in year 3. Annual herbicide spraying was the only maintenance cost included in this study. Discounted development costs over a 3-year development period were estimated to be $58.01/acre, with an annual maintenance cost of $24.18/acre. The itemized costs involved in these estimates are provided in Table 3.6.

Table 3.5. Cost categories and estimated costs for planting warm-season native grasses in the Dakota pothole region (from Lokemoen 1984).

Materials and maintenance	Cost
Materials (per acre)	
Big bluestem (5.3 pounds pure live seed)	$19.88
Indiangrass (3.0)	11.25
Switchgrass (0.9)	2.51
Total	33.64
Correction factor (28% of materials)[a]	9.42
Total materials cost	$43.06
Maintenance (per acre)	
Labor (0.05 hr)	$ 0.32
Transportation (0.625 mi)	0.21
Spraying (0.025 ac)	0.19
Burning (every 5 years)	0.72
Total annual maintenance cost	$ 1.44

[a] Costs increased 28% because cover is not available during the 4-year seeding period and there is an estimated 20% failure rate.

Table 3.6. Cost categories and estimated costs for planting native grass in North Dakota.[a]

Year	Activity	Cost/acre[b]
1	Fallow (tillage cost offset by nursery crop)	$ 0
2	Seedbed preparation, seed, and seeding	30.00
	Fertilization	14.00
	Initial herbicide spraying	7.00
3	Reseeding (20% of area)	10.20
	Follow-up herbicide spraying (15% of area)	0.83
4-100	Herbicide spraying (10% of area each year)	0.90

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

[b] These costs are not summed to a single total cost because the activities occur in different years. An appropriate discount factor based on a selected discount rate must be used to determine the present worth of each activity. For the Garrison Diversion Unit study, the total discounted cost was estimated to be $58.01/acre for establishing native grass and $24.18/acre to maintain the planted grass through 100 years, based on a discount rate of 3-1/8%. The annual cost per acre was estimated to be $2.70.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Establishment of tall, warm-season native grasses can theoretically be accomplished on any upland site where site and climate are suitable (see Duebbert et al. 1981). In practice, however, establishment of seeded grasslands may best be done on croplands or other lands lacking native vegetation. Duebbert et al. (1981) recommended that all native prairies on wildlife management areas should be maintained in their native condition. For purposes of this model, it is assumed that the establishment of native grasses can occur on any upland site other than native prairie.

Minimum management area. It is theoretically possible, although not necessarily practical, to plant any size area to native grasses. However, there are practical limits in terms of cost-effectiveness as to the minimum

06)

area that should be considered for planting native grasses. Cost information (Lokemoen 1984) and planting guidelines (Duebbert et al. 1981) are typically presented on the basis of 1.0 acre; therefore, 1.0 acre is assumed to be the minimum practical area potentially planted to native grasses.

Model Description

Overview. This model describes the relationships between the action of planting native grasses and selected habitat variables (Table 3.7). The effects on habitat variables from planting native grasses are functionally similar to those from planting dense nesting cover. This model, therefore, is very similar to that described for planting dense nesting cover. The variables that are expected to change as a result of different amounts of planted native grasses are those that reflect the amount and distribution of cover types. Structural habitat variables within planted native grasses will change over time but not in response to the area of native grasses planted. Average annual values for such variables must be estimated in order to determine average annual Habitat Units for a given species. This can be accomplished by estimating values for each variable at selected target years over the life of the management action. Planting native grasses creates permanent cover (Duebbert et al. 1981). The life of the management action, therefore, can be assumed to equal the period of analysis on a given study area. Lokemoen (1984) assigned a life of 50 years to planted native grasses based on an assumed maximum planning period.

In order to determine impacts of planting native grasses on the six wildlife species identified in the Introduction, average annual values must be estimated for the following variables over the assumed life of the planted native grass cover, or over the period of analysis used in a given project: (1) average visual obstruction measurement, (2) percent herbaceous canopy cover, (3) proportion of herbaceous canopy that is grass, and (4) maximum height of grass canopy.

Area of specified nonwetland cover type (ACT_j). Planting native grasses involves the change of one nonwetland cover type (the host cover type) to another. In most situations, the creation of the native grassland cover type that results from planting native grasses occurs at the expense of cropland, although it is not restricted to cropland types. The effect of planting native grasses is to increment the area of native grassland by the amount of dense nesting cover planted and to decrement the area of the host cover type (usually cropland) by a similar amount. The change in area for native grassland and host cover types are expressed in Equations 3.8 and 3.9, respectively.

Table 3.7. Habitat variables potentially affected by planting native grasses.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)	X	X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	
Distance to a wetland ≥0.4 ha (DW)	X	X

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of planting native grasses. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

$$ACT_2 = ACT_{2B} + ANG \qquad (3.8)$$

where ACT_2 = the area of native grassland (nonwetland cover type 2) following a management action

ACT_{2B} = the area of native grassland (nonwetland cover type 2) prior to management

ANG = the area of native grasses planted

$$ACT_j = ACT_{jB} - ANG_j \tag{3.9}$$

where ACT_j = the area of host cover type j following a management action

ACT_{jB} = the area of host cover type j prior to management

ANG_j = the area of native grasses planted in host cover type j

Percent of an area in cropland (PC). As discussed above, planting native grasses will usually occur in existing cropland. The usual effect of planting native grasses is to reduce the area of cropland and, therefore, the proportion of an area in cropland. Native grasses planted in cover types other than cropland will not change the proportion of an area in cropland. This simple relationship is expressed in Equation 3.10.

$$PC = \left[\frac{ACT_{3B} - ANG_3}{\text{Total study area}}\right] \times 100 \tag{3.10}$$

where PC = the percent of an area in cropland following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ANG_3 = the area of dense nesting cover planted in cropland (nonwetland cover type 3)

Percent of cropland cover type in corn or grain crops (PCG). Planting native grasses in cropland may cause a postive, neutral, or negative change in the proportion of cropland in corn or other grain crops. If native grasses are assumed to be planted in different crop types in the same proportion as the different crop types occur, then the impact on this variable will be neutral (note, however, that the absolute area of cropland will decrease in this situation, according to Equation 3.9). If the preceding assumption is invalid, then the effect on the variable can be positive or negative, depending on the distribution of the planted cover. The value of this variable following planting of native grasses can be determined with Equation 3.11.

$$PCG = \left[\frac{ACG_B - ANGCG}{ACT_{3B} - ANG_3}\right] \times 100 \tag{3.11}$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn or other grain crops prior to management

$ANGCG$ = the area of native grasses planted in cropland producing corn or other grain crops

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ANG_3 = the area of native grasses planted in cropland (nonwetland cover type 3)

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. Planting of native grasses in cropland or in tame grassland will increase the area of idle land if the planted native grassland is neither hayed nor grazed. Duebbert et al. (1981) recommended that grasslands managed for wildlife should not have annual grazing or mowing. It is assumed that planted native grasses will not be mowed or grazed and that it will, therefore, meet the definition of idle land. The effect of planting native grasses on the area of idle land is to simply increase the area of idle land by the area of native grasses planted. Equation 3.12 presents this relationship with idle land expressed as a proportion of a study area.

$$PIL = \left[\frac{AIL_B + ANG}{\text{Total study area}} \right] \times 100 \qquad (3.12)$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

ANG = the area of dense nesting cover planted in cropland cover types or in other cover types that are grazed or mowed.

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km^2 sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed and do not support crops. The amount of idle cover within each 4-ha cell is not considered in calculating this variable. If it is assumed that native grassland is created in cover types that are not classified as idle cover, and that the native grassland is not hayed or grazed (i.e., it is idle cover), then every 4 ha converted to native grassland increases the number of idle 4-ha grids by one. However, this is a conservative estimate, since a grid is also included as an idle grid if it borders idle cover in an adjacent grid. If only 4 ha of cropland is converted to grassland, then three to five grids may be changed to an idle classification (Figure 3.2). Several grids may also be changed to an idle classification even if <4 ha of cropland is converted to grassland, depending on the distribution of the planted cover. The amount and distribution of nonidle cover types converted to native grassland (e.g., whether one contiguous block or scattered smaller blocks are planted to native grasses) will determine the ratio between area of cropland converted to tame grassland and the increase in the number of grids classified as idle. Hypothetical applications of this management action on a study area map can be used to determine the actual ratio between area converted to native grassland and number of idle grid cells. Equation 3.13 presents the simplest, most conservative, case where each 4 ha converted to native grassland increases the number of grid cells with idle cover by one.

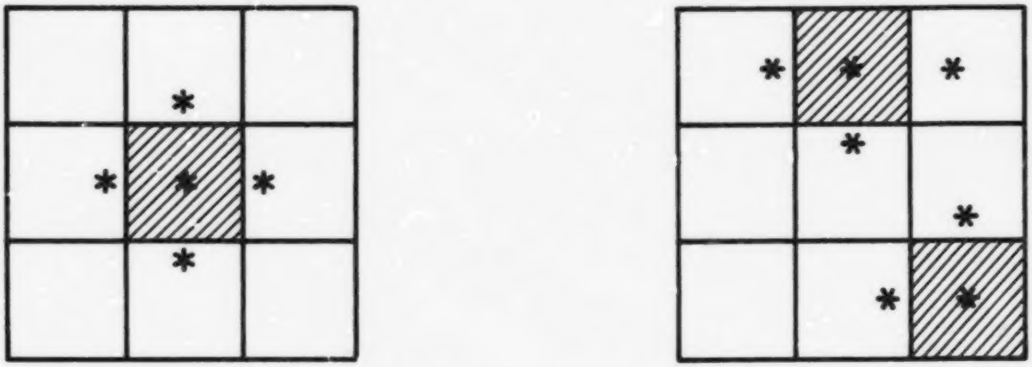


Figure 3.2. Examples of how the distribution of planted native grasses changes the ratio of planted cover area to number of idle grid cells (shaded grid cells = 4 ha of planted cover, * indicates blocks classified as idle cover as a result. Based on assumption that adjacent grids are not classified as idle prior to planting).

$$\mathrm{DIC} = \mathrm{NGIL}_B + \left[\frac{\mathrm{ANG}}{4} \times \frac{259}{\text{Total study area (ha)}} \right] \qquad (3.13)$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

NGIL_B = the number of 4-ha grid cells per 2.59 km² that contain or border idle cover prior to management

ANG = the area (ha) of native grasses planted (based on the assumption that all planting of native grasses will be done in cover types that do not meet the definition of idle land)

Equation 3.13 produces an output in terms of number of grid cells per 2.59 km². Users may wish to change the denominator to the ANG term (i.e., 4) to more accurately reflect the expected ratio of planted hectares to idle grid cells.

Distance to wetland ≥0.4 ha (DW). Planting native grasses may decrease or increase the average distance from native grassland to a wetland ≥0.4 ha. An estimate of this variable can be made by determining a weighted (by area) average distance from existing native grassland and from planted native grassland (Equation 3.14). If no native grassland exists prior to management, then the distance to wetland from any created native grassland can be assumed to be the same as for the host cover type.

$$\mathrm{DW}_2 = \frac{(\mathrm{DW}_{2B} \times \mathrm{ACT}_{2B}) + (\mathrm{DW}_{jB} \times \mathrm{ANG}_j)}{\mathrm{ACT}_{2B} + \mathrm{ANG}_j} \qquad (3.14)$$

where DW_2 = the distance to a wetland ≥0.4 ha from native grassland (nonwetland cover type 2) following a management action

DW_{2B} = the distance to a wetland ≥0.4 ha from native grassland (nonwetland cover type 2) prior to management

ACT_{2B} = the area of native grassland (nonwetland cover type 2) present prior to management

DW_{jB} = the distance to a wetland ≥0.4 ha from host cover type j prior to management

ANG_j = the area of native grasses planted in host cover type j

Model Relationships

The presumed relationships between planting native grasses and a number of habitat variables were described in the preceding section. Table 3.8 presents a summary of the variables discussed in this model and a reference to the equation where each relationship is presented.

Table 3.8. A summary of the habitat variables potentially affected by planting native grasses.

Variable (acronym)	Equation(s)	Page
Area of specified nonwetland cover type (ACT_j)	3.8, 3.9	3.18-3.19
Percent of area in cropland (PC)	3.10	3.19
Percent of cropland cover type in corn or other grain crops (PCG)	3.11	3.19
Percent of area in idle land (PIL)	3.12	3.20
Distribution of idle cover (DIC)	3.13	3.22
Distance to wetland ≥0.4 ha (DW)	3.14	3.22

Application of the Model

This model can be used to evaluate the influence of planting native grasses on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the model user must provide site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all habitat variables.

2. The area of potential host cover types and native grassland at initial conditions, and the total area of all cover types.

3. An estimate of the ratio between the area of a host cover type planted to native grasses and the number of grid cells that will contain or border idle cover as a result. This ratio can be estimated by assuming a fixed, site-specific pattern of planting.

LITERATURE CITED

Duebbert, H.F., E.T. Jacobson, K.F. Higgins, and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the Prairie Pothole region. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. No. 234. 21 pp.

Kirsch, L.M., and K.F. Higgins. 1976. Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4(1):16-20.

Kirsch, L.M., H.F. Duebbert, and A.D. Kruse. 1978. Grazing and haying effects on habitat of upland nesting birds. Trans. N. Am. Wildl. Nat. Resour. Conf. 43:486-497.

Klett, A.T., H.F. Duebbert, and G.L. Heismeyer. 1984. Use of seeded native grasses as nesting cover by ducks. Wildl. Soc. Bull. 12(2):134-138.

Kohn, S.C., R.L. Linder, and G.D. Kobriger. 1982. Sharp-tailed grouse nesting habitat in southwestern North Dakota. Proc. Wildlife-Livestock Relationships Symp. 10:166-174.

Lokemoen, J.T. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

3. UPLAND VEGETATION DEVELOPMENT
c. Woodland development

MANAGEMENT ACTION INFORMATION

Purpose

Woodland development consists of developing wooded areas to provide wildlife cover and travel lanes. The only species of the six discussed in the Introduction that would show benefits from the development of woodlands are the sharp-tailed grouse and gray partridge. Woodlands, as used here, refer to wooded fencerows or shelterbelts rather than to extensive forested areas.

Effects of Management Action

In the strictest sense, woodland development merely changes one existing cover type to a different cover type, i.e., from nonwooded to wooded. As a result, the area of the woodland cover type will increase in response to implementation of this action, while the area of host cover types (i.e., the existing cover type that is changed to woodland) will decrease. The relative proportion of cover types will also change as a result of woodland development. Individual habitat variables will change over time in the newly created type, but these changes will be a function of environmental influences, rather than a function of the amount of woodland that is developed.

Several studies have been conducted to determine the value of fencerows to wildlife beyond the six species considered here. A detailed review of the literature pertaining to wildlife use of shelterbelts and of the important features of shelterbelts contributing to high species diversity is provided by Schroeder (1986), from which the following brief discussion is adapted.

Development of woodlands in the Great Plains adds to a limited resource of wooded habitat. Less than 3% of the land area in the Great Plains is in wooded cover (Griffith 1976). Shelterbelts provide wooded habitat for a large variety of birds and other wildlife that would not otherwise be present (Popowski 1976). Shelterbelts in North Dakota contribute significantly to the habitat needs of the ring-necked pheasant (Phasianus colchicus), gray partridge, sharp-tailed grouse, mourning dove (Zenaida macroura), cottontail rabbit (Sylvilagus floridanus), fox squirrel (Sciurus niger), and a variety of songbirds (Podoll 1979). Sixty-four species of birds were noted as using shelterbelts during the breeding season in North Dakota (Cassell and Wiehe 1980), and 44 species of birds used shelterbelts during the breeding season in

073

South Dakota (Martin 1978). Shelterbelts in the Great Plains occur as isolated woody habitats in large expanses of grassland and cropland. These wooded islands provide elevated song perches for breeding grassland and woodland birds, and feeding and nesting sites for migratory birds.

Shelterbelts with about 10 rows of shrubs and trees and ≥1.2 ha in size were the most heavily used by wildlife in Kansas (Schwilling 1982). Multirow shelterbelts in the Great Plains provide winter cover for ring-necked pheasants, gray partridge, sharp-tailed grouse, cottontail rabbits, fox squirrels, and songbirds, while single-row shelterbelts provide winter cover for only the gray partridge (Podoll 1979). The best configuration of multirow shelterbelts for wildlife is to have tall trees in the middle rows and lower shrubs in the outer rows.

The number of breeding bird species was positively correlated with shelterbelt area in both North Dakota (Cassell and Wiehe 1980) and South Dakota (Martin 1981). Shelterbelt size was positively correlated with species richness of small mammals in Minnesota (Yahner 1983b).

A created woodland or shelterbelt requires time to reach its full habitat potential. Most birds in North Dakota shelterbelts used belts >5 years old (Cassell and Wiehe 1980). Older shelterbelts supported more breeding species, and raptors and hole-nesting birds appeared to prefer shelterbelts >40 years old.

Yahner (1983a) discussed specific management recommendations to enhance bird species richness in shelterbelts related to the following attributes: plant species composition, size, number of rows, spacing, grazing, mowing, snag availability, food plots, and adjacent tillage practices.

Maintenance and Management

Woodland development is relatively labor intensive and requires periodic maintenance to ensure the eventual establishment of a mature wooded habitat. Establishment of a woodland requires site preparation, which includes catching and storing moisture, reducing grass and weed competition, and soil preparation (Shaw 1980). Snowfences may be used to catch and store moisture. Reduced competition can be achieved by summer fallowing on medium to heavy soils the year before planting; cover crops are necessary on sandy soils to avoid wind erosion. Depending on the location of the proposed planting, drip irrigation may be necessary to ensure establishment of seedlings. Fencing may also be necessary to protect seedlings from livestock. Maintenance activities involve clean cultivation between rows to minimize competition for growing space and water.

The life span of a planted woodland depends on the species of trees and shrubs planted. The Soil Conservation Service (SCS) estimates a life span of 80 years for planted hardwoods (walnut), 25 years for conifers (pine or spruce), and 25 years for hedgerows or windbreaks (U.S. Soil Conservation Service 1983). Woodland development was assumed to have a lifespan of 50 years on the Garrison Diversion Unit study in North Dakota.

Plants may be spaced differently depending on the species involved. For purposes of establishing farmstead windbreaks, Shaw (1980) recommended that within-row spacing be 3 to 5 feet for hardwood shrubs, 5 to 7 feet for junipers, 8 to 12 feet for evergreen trees, and 10 to 14 feet for broadleaved trees, and that rows of trees be spaced 16 to 20 feet apart. Spacing between rows was assumed to be 30 feet on the Garrison Diversion Unit study.

Labor and Materials

The costs of establishing woodlands include development, maintenance, and replacement costs. As noted previously, the lifespan for created woodlands was estimated to be 50 years on the Garrison Diversion Unit study. Development costs include site preparation, materials (seedlings), and planting. For purposes of this discussion, neither drip irrigation nor grazing exclusion are considered to be costs of woodland development. Maintenance costs are incurred annually as the result of cultivating to reduce competition from other vegetation. No removal or thinning costs are included, since this can be eliminated by wide initial spacing of seedlings.

The development cost for planting woodlands was estimated for the Garrison Diversion Unit study to be $174.28/acre (based on planting 20 rows of bare root seedlings in rows spaced 30 feet apart) (Table 3.9). Annual operation and maintenance costs were estimated as 2% of the development costs or $3.49/acre. Windbreak establishment was estimated by the SCS to cost $240 per 0.5 mile row, with 30% annual operation and maintenance costs (U.S. Soil Conservation Service 1983). The high O&M cost estimated by SCS apparently reflects estimated cultivation costs.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Woodland development can presumably be done in virtually any upland cover type. In practice, however, this activity will probably be restricted to introduced grasslands or cropland, presuming that the recommendation by Duebbert et al. (1981) that native prairies on wildlife management areas be maintained in their native condition, is followed.

Minimum management area. It is theoretically possible, though not necessarily practical, to plant a single tree and term it a woodland. In terms of wildlife use, however, a single tree obviously does not provide the functions necessary to support species requiring woodland habitat. Unfortunately, no clear definition exists on when a planting of trees becomes a woodland from a wildlife perspective. Users must define a minimum area (or minimum length) of woodland to be planted as part of the specifications of this management action.

08J

Table 3.9. Cost categories and estimated costs for woodland development in North Dakota.[a]

Activity	Cost/acre
Land preparation	$ 20.00
Planting	154.28[b]
Total development cost	174.28
Annual maintenance (2% of development cost)	$ 3.49

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

[b] Costs based on $10.15/100-ft row, with rows spaced 30 ft apart. Cost of 20, 100-ft rows is $203.00 and encompasses an area of 57,000 ft^2 (100 ft long x 30 ft wide x 19 strips between rows). Cost per acre equals $154.28 ($203.00/57,000 ft^2 x 43,560 ft^2/acre).

Model Description

Overview. This model describes the relationship between the action of woodland development and selected habitat variables (Table 3.10). The only variables that are expected to change as a result of different amounts of woodland developed are those that reflect the amount and distribution of cover types. Structural habitat variables within planted woodland will change over time, but not in response to the amount of woodland developed. Average annual values for such variables must be estimated in order to determine Average Annual Habitat Units for a given species. This can be done by estimating values for each variable at selected target years over the life of the management action. Habitat variables that describe the physical structure of woodland habitat were not included in any of the HSI models for the six species identified in the Introduction. Therefore, average annual values are not necessary for woodland structural variables to evaluate the habitat suitability for the six species considered here. Addition of species more closely tied to woodland habitats may require that predictions of change over time be made for structural variables.

Table 3.10. Habitat variables potentially affected by woodland development.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)	X	X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	
Percent woody vegetation (PWV)	X	
Distance to a wetland ≥0.4 ha (DW)	X	X

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of woodland development. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

Area of specified nonwetland cover type (ACT_j). Woodland development involves the change of one nonwetland cover type (the host cover type) to another (planted woodlands). In most situations, the creation of woodlands for wildlife benefits will be done at the expense of croplands, although it is technically possible to develop woodlands on any upland cover type. The effect of planting woodland is to increment the area of woodland by the amount of woodland planted and to decrement the area of the host cover type by a similar amount. The change in area for woodland and host cover types are expressed in Equations 3.15 and 3.16, respectively.

$$ACT_5 = ACT_{5B} + AWOOD \qquad (3.15)$$

where ACT_5 = the area of woodland (nonwetland cover type 5) following a management action

ACT_{5B} = the area of woodland (nonwetland cover type 5) prior to management

AWOOD = the area of woodland planted

$$ACT_j = ACT_{jB} - AWOOD_j \qquad (3.16)$$

where ACT_j = the area of host cover type j following a management action

ACT_{jB} = the area of host cover type j prior to management

$AWOOD_j$ = the area of woodland planted in host cover type j

Percent of area in cropland (PC). If woodlands are developed in cropland cover types, then the relative area of cropland will be reduced accordingly. If woodlands are planted in cover types other than cropland, then the action of woodland development will have no effect on this variable. The impact of woodland development on this variable when cropland is the host cover type is expressed in Equation 3.17.

$$PC = \left[\frac{ACT_{3B} - AWOOD_3}{\text{Total study area}}\right] \times 100 \qquad (3.17)$$

where PC = the percent of an area in cropland following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

$AWOOD_3$ = the area of woodland planted in cropland (nonwetland cover type 3)

Percent of cropland cover type in corn or grain crops (PCG). Planting woodland in cropland may cause a positive, neutral, or negative change in the proportion of the cropland cover type in corn or other grain crops. If woodlands are assumed to be planted in different crop types in the same proportion as the different crop types occur, then the impact on this variable will be neutral (note, however, that the absolute area of cropland will decrease in this situation, according to Equation 3.16). If the preceding assumption is not valid, then the effect of woodland development on the value of this variable can be determined with Equation 3.18.

$$PCG = \left[\frac{ACG_B - AWDCG}{ACT_{3B} - AWOOD_3}\right] \times 100 \qquad (3.18)$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn or other grain crops prior to management

$AWDCG$ = the area of woodland planted in cropland producing corn or other grain crops

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

$AWOOD_3$ = the area of woodland planted in cropland (nonwetland cover type 3)

Percent of area in pasture/hayland (PPH). Woodland development that occurs in pasture or hayland will result in a decrease in this variable, similar to the effect on the percent of area in cropland. Pasture/hayland may exist in either native grassland or tame grassland, both of which are presumably available for planting woodland, although native grasses would not likely be converted to woodlands for wildlife management purposes. If woodlands are planted in cover types that are not currently used for pasture/hayland, then the action of woodland development will have no effect on this variable. The impact of woodland development on this variable when pasture/hayland is the land use in the host cover type is expressed in Equation 3.19.

$$PPH = \left[\frac{APH - AWDPH}{\text{Total study area}}\right] \times 100 \qquad (3.19)$$

where PPH = the percent of an area in pasture/hayland following a management action

APH = the area of cover types that are in pasture/hayland prior to management

AWDPH = the area of woodland planted in nonwetland cover types that are pasture/hayland

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. Planting woodlands in cropland or in grazed or mowed grasslands will increase the area of idle land if the created woodland is not grazed or mowed. It is assumed that created woodlands will be neither grazed nor mowed and, therefore, will meet the definition of idle land. The effect of developing woodlands on this variable is to simply increase the area of idle land by the area of woodlands created. Equation 3.20 presents this relationship with idle land expressed as a proportion of a study area.

$$PIL = \left[\frac{AIL_B + AWOOD}{\text{Total study area}}\right] \times 100 \tag{3.20}$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

AWOOD = the area of woodland planted in cropland or grassland (assuming that grasslands are either grazed or mowed)

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km^2 sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed and do not support crops. The total amount of idle cover within each 4-ha cell is not considered in calculating this variable. If it is assumed that woodlands are developed in cover types that are not classified as idle cover, then, at a minimum, every 4 ha of woodland developed will increase the number of idle 4-ha grids by one. This is a conservative estimate for two reasons: (1) a grid is counted as an idle grid if it borders idle cover in an adjacent grid. This means that >1 grid may be changed to an idle classification for every 4 ha of woodland developed, depending on the placement of the planted woodland; and (2) woodlands will generally be planted as rectangular shelterbelts rather than square grids, thus 4 ha of planted woodlands will likely extend over several grids. For example, if a shelterbelt is assumed to be 40 m wide, then 4 ha of such a shelterbelt may change the classification of a variable number of square 4-ha grids to an idle classification (Figure 3.3). In order to properly evaluate the effect of planting woodlands on the distribution of idle cover, it is necessary to determine the number of grids converted to an idle classification for every unit (e.g., 1 ha, 4 ha) of woodland planted. Hypothetical applications of this management action on a study area map can be used to determine the actual ratio of newly idle grids to a unit of woodland planted. Equation 3.21 presents the simplest and most conservative case, where each 4 ha converted to woodland increases the number of idle grid cells by one.

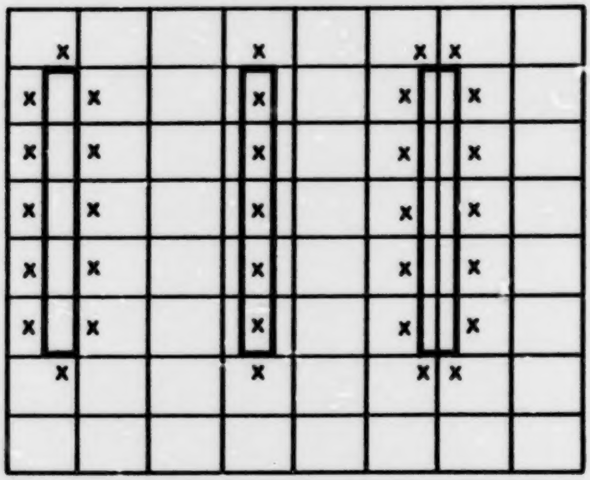


Figure 3.3. Examples of how the area and width of planted woodland changes the ratio of planted cover area to number of idle grid cells (x indicates blocks classified as idle cover as a result of planting 4 ha of woodland that is 40 m wide. Based on assumption that adjacent grids are not classified as idle prior to planting).

$$\mathrm{DIC} = \mathrm{NGIL}_B \times \left[\frac{\mathrm{AWOOD}}{4} \times \frac{259}{\text{Total study area (ha)}}\right] \tag{3.21}$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

NGIL_B = the number of 4-ha grids cells per 2.59 km² that contain or border idle cover prior to management

AWOOD = the area of woodland planted in cropland or grasslands (assuming that grasslands are either grazed or mowed)

Equation 3.21 produces an output in terms of number of grid cells per 2.59 km². Users may wish to change the denominator to the AWOOD term (i.e., 4) to more accurately reflect the expected ratio of planted hectares to idle grid cells.

Percent woody vegetation (PWV). This variable refers to the proportion of an entire study area that is in wooded cover types. It does not refer to the canopy cover provided by woody vegetation in any given cover type. Since the primary effect of developing woodland is to increase the area of wooded cover types, the percent woody vegetation also increases with this action. This simple relationship is expressed in Equation 3.22.

$$PWV = \left[\frac{ACT_{5B} + AWOOD}{\text{Total study area}}\right] \times 100 \tag{3.22}$$

where PWV = the percent of an area in woody vegetation (i.e., wooded cover types) following a management action

ACT_{5B} = the area of woodland (nonwetland cover type 5) prior to management

AWOOD = the area of woodland planted

Distance to a wetland >0.4 ha (DW). Planting woodland may decrease or increase the average distance from woodland to a wetland ≥0.4 ha. An estimate of this variable may be made by determining a weighted (by area) average distance from existing woodland and from planted woodland (Equation 3.23). If no woodland exists prior to management, then the distance to wetland from any created woodland can be assumed to be the same as for the host cover type. Either of these approaches will yield an average value that will not be as precise as an estimate derived from measuring actual distances from developed woodland, either from maps or in the field.

$$DW_5 = \frac{(DW_{5B} \times ACT_{5B}) + (DW_{jB} \times AWOOD_j)}{ACT_{5B} + AWOOD_j} \qquad (3.23)$$

where DW_5 = the average distance to a wetland ≥0.4 ha from all woodlands (nonwetland cover type 5) following a management action

DW_{5B} = the distance to a wetland ≥0.4 ha from woodlands (nonwetland cover type 5) prior to management

ACT_{5B} = the area of woodland (nonwetland cover type 5) present prior to management

DW_{jB} = the distance to a wetland ≥0.4 ha from host cover type j prior to management

$AWOOD_j$ = the area of woodland planted in host cover type j

Model Relationships

The presumed relationships between planting woodland and a number of habitat variables were described in the preceding section. Table 3.11 presents a summary of the variables discussed in this model and a reference to the equation where each relationship is presented.

Application of the Model

This model can be used to evaluate the influence of woodland development on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the user must provide site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all variables.

2. The area of potential host cover types and woodland at initital conditions, and the total area of all cover types.

3. The maximum area of woodlands that can be developed, if it is equal to some value other than the area of the host cover types.

4. An estimate of the ratio between the area of a host cover type planted to woodland and the number of grid cells that will contain or border idle cover as a result. This ratio can be estimated by assuming a fixed, site-specific pattern of planting.

5. An estimate of the area of tame and native grasslands that are either grazed by domestic livestock or mowed under initial conditions.

Table 3.11. A summary of the habitat variables potentially affected by woodland development.

Variable (acronym)	Equation(s)	Page
Area of specified nonwetland cover type (ACT_j)	3.15, 3.16	3.30
Percent of area in cropland (PC)	3.17	3.30
Percent of cropland cover type in corn or other grain crops (PCG)	3.18	3.31
Percent of area in pasture/hayland (PPH)	3.19	3.31
Percent of area in idle land (PIL)	3.20	3.32
Distribution of idle cover (DIC)	3.21	3.33
Percent woody vegetation (PWV)	3.22	3.34
Distance to a wetland ≥0.4 ha (DW)	3.23	3.35

LITERATURE CITED

Cassell, J.F., and J.M. Wiehe. 1980. Uses of shelterbelts by birds. Pages 78-87 in R.M. DeGraaf, tech. coord. Management of Western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Griffith, P.W. 1976. Introduction to the problem. Pages 3-7 in R.W. Tinus, ed. Shelterbelts on the Great Plains. Great Plains Agric. Council Publ. 78.

Martin, T.E. 1978. Diversity and density of shelterbelt bird communities. M.S. Thesis. South Dakota State University, Brookings. 174 pp.

__________. 1981. Limitation in small habitat islands: chance or competition? Auk 98(4):715-734.

Podoll, E.B. 1979. Utilization of windbreaks by wildlife. Proc. For. Comm. Great Plains Agric. Council 31:121-128.

Popowski, J. 1976. Role of windbreaks for wildlife. Pages 110-111 in R.W. Tinus, ed. Shelterbelts on the Great Plains. Great Plains Agric. Council Publ. 78.

Schroeder, R.L. 1986. Habitat Suitability Index models: wildlife species richness in shelterbelts. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.128). 17 pp.

Schwilling, M.D. 1982. Nongame wildlife in windbreaks. Proc. For. Comm. Great Plains Agric. Council 34:258-262.

Shaw, D.L. 1980. The farmstead windbreak. Colorado State Forest Service and Colorado State University. 42 pp.

U.S. Soil Conservation Service. 1983. South Dakota Technical Guide, 200-VI-CRH, Amend. SD12, 2/28/83. U.S. Soil Conservation Service, Pierre, SD.

Yahner, R.H. 1983a. Seasonal dynamics, habitat relationships, and management of avifauna in farmstead shelterbelts. J. Wildl. Manage. 47(1):85-104.

___________. 1983b. Small mammals in farmstead shelterbelts: habitat correlates of seasonal abundance and community structure. J. Wildl. Manage. 47(1):74-84.

4. UPLAND VEGETATION MAINTENANCE/MANAGEMENT

a. Prescribed burning

MANAGEMENT ACTION INFORMATION

Purpose

Prescribed burning is the preferred method of rejuvenation to maintain the vigor of seeded native grasses (Duebbert et al. 1981). The reduction of vigor due to the accumulation of litter may be reflected in size, general health, or flowering activity (Daubenmire 1968). Reduced vigor is related to nitrogen deficiency resulting from a condition commonly referred to as "sod-bound" (Canode 1965, cited by Duebbert et al. 1981). Other uses of fire to benefit wildlife include the suppression of woody plants (Vogl 1967; Gartner and Thompson 1972; Launchbaugh 1972; Kirsch and Kruse 1973; Forde 1983; Forde et al. 1984), suppression of wildfire hazard and removal of excessive mulch accumulation (Launchbaugh 1972), creation of diverse habitat conditions (Wright 1974a), maintenance of native grassland (Kirsch and Kruse 1973) and removal of marsh vegetation to create more edge and open water for waterfowl (Schlichtemeier 1967). For purposes of this discussion, prescribed burning is assumed to refer specifically to the use of fire on a specified frequency in native grasslands for the purpose of maintaining the vigor of vegetation and the dominance of native herbaceous vegetation. Other, less desirable, options for achieving these goals in native grasslands include haying and grazing (Duebbert et al. 1981). Rejuvenation of introduced cool-season grasses and legumes is best accomplished by mechanical tillage and replanting (Duebbert et al. 1981).

Effects of Management Action

Numerous studies have been done on the short-term effects of prescribed burning on vegetative communities; fewer studies on the long-term effects of burning have been reported. Reactions to fire vary with "...grassland type, fuels, soils, moisture conditions, fire frequencies, and burning times" (Vogl 1974:158). The timing of a burn, both in time of year and time of day, may be as important as the fact of the burn itself (Daubenmire 1968). Furthermore, few fires are described quantitatively with standard descriptors, making it "...impossible, or at best very difficult, to correlate and communicate results of different studies" (Rothermal and Deeming 1980). The results of most studies appear to be site specific; consequently, generalizations of the impacts of burning on vegetative communities are difficult to make.

Burning in grassland has generally been found "...to increase the production of most grassland vegetation, but occasionally it is ineffective and sometimes even deleterious to individual species" (Vogl 1974:157). Table 4.1 summarizes the impacts of burning on the productivity of vegetation from several studies. In general, litter accumulation reduces the vigor of grasses to a low level, where it will remain indefinitely without fire or some other form of disturbance (Daubenmire 1968). Several theories have been proposed to explain the observed increases in plant production following burning. In Ohio, Annala and Kapustka (1982) concluded that the nutrients from ash do not necessarily enrich the burned site nor increase microbial activity. In fact, the reduction in mulch resulting from burning may reduce soil moisture and microbial activity (Dix 1960). The most often offered explanation for the observed increase in productivity following burning is that plants respond to the warmer soil temperatures on burned sites in the early part of the growing season compared to unburned sites (Aldous 1934; Ehrenreich and Aikman 1963; Hulbert 1969; Adams and Anderson 1978; Rice and Parenti 1978). The warmer temperatures are a function both of increased sunlight reaching the soil surface and the dark color of the ash.

Burning can change plant species composition, depending on the timing of the burn. Spring burning has been reported to significantly reduce the abundance of Kentucky bluegrass (Poa pratensis), a cool season perennial (Ehrenreich and Aikman 1963; Daubenmire 1968; Anderson et al. 1970; Anderson 1972; Smith and Owensby 1972). In Wisconsin, fall burning of tallgrass prairie also reduced bluegrass significantly (Anderson 1972). Spring burning generally favors the warm-season native plants (e.g., Andropogon spp., Sorghastrum spp., and Panicum spp.), because they are dormant at the time of burning and are, therefore, undamaged by fire (Daubenmire 1968). Other authors also report the favoring of warm-season native species as a result of spring burning (Anderson et al. 1970; Anderson 1972; Wright 1974a).

Individual plant species may respond quite differently under various burning conditions throughout the species' range. For example, little bluestem (Andropogon scoparius) increased with burning in a Wisconsin prairie (Anderson 1972), in a mesic native prairie in Iowa (Ehrenreich and Aikman 1963), in an undisturbed bluestem prairie in Kansas (Hulbert 1969), and in a tallgrass prairie in Missouri (Kucera and Ehrenreich 1962). Little bluestem and other perennial grasses decreased in total ground coverage during the first year following burning in Wind Cave National Park, South Dakota (Forde et al. 1984), but increased dramatically in the second and third years following burning. The effects of burning on little bluestem in the Flint Hills, Kansas, was unclear, with little difference in the number of plants on burned and unburned sites (Smith and Owensby 1972). Little bluestem in west Texas grasslands is expected to have increased productivity following burning unless the burn occurs following a period of below normal precipitation (Wright 1974b).

Even though the response of vegetation to burning will be different with different burning conditions, some generalizations are possible. In dry areas, the removal of litter by burning may reduce subsequent yields due to decreased soil moisture, but yields may increase in wetter areas due to the reduced litter accumulation (Anderson et al. 1970). Based on a summary of

092

Table 4.1. Summary of burning impacts on productivity or grassland vegetation.

Habitat type (location)	Time of burn	Initial response to burning[a]	Source
Tallgrass prairie (WI)	Early spring	+[b]	Peet (1971, cited by Anderson 1972)
Brush prairie savanna (WI)	Spring	+	Vogl (1967)
Tallgrass prairie (OH)	May	+	Annala and Kapustka (1982)
Mesic prairie (IA)	Late winter, early spring	+	Ehrenreich and Aikman (1963)
Big bluestem grassland (IL)	Spring	+	Hadley and Kieckhefer (1963)
Indiangrass grassland (IL)	Spring	+	Hadley and Kieckhefer (1963)
Mid-grass prairie (ND)	May	+	Kirsch and Kruse (1973)
Bluestem grassland (SD)	Late spring	0	Gartner and Thompson (1972)
Tallgrass prairie (MO)	Spring	+	Kucera and Ehrenreich (1962)
Planted western wheatgrass[c] (KS)	April/May	+	Launchbaugh (1972)
Bluestem prairie (KS)	Late spring	0	Smith and Owensby (1972)
Bluestem prairie (KS)	Fall, early spring, midspring	-	Smith and Owensby (1972)
Bluestem range (KS)	Early to midspring	-	Anderson et al. (1970)
Bluestem range (KS)	Late spring	0	Anderson et al. (1970)
Bluestem grassland (KS)	Spring	+,-	Hensel (1923)
Bluestem grassland (KS)	Late fall, early to late spring	-	Aldous (1934)
Mixed prairie (KS)	Late fall, early spring	-	Hopkins et al. (1948)
Blue grama grassland (KS)	Early spring	-	Launchbaugh (1964)
Bluestem prairie (KS)	Early April	+	Hulbert (1969)
Tallgrass prairie (OK)	Early spring	+	Rice and Parenti (1978)
Little bluestem grassland (OK)	November	+	Adams and Anderson (1978)

Table 4.1.

Habitat type (location)	Time of burn
Perennial grassland (general)	-
Annual grassland (general)	-
Grasslands (general)	-
Semiarid mixed prairie (general)	-
Tallgrass prairie (general)	-

[a] Response is typically measured differently in different studies, s each other. A positive response may indicate greater forage yield, more seed production. The responses indicated here generally refer following burning.

[b] + = greater response on burned sites; - = lower response on burned

[c] Scientific names of plants not included in text: Western wheatgra

(Concluded)

Initial response[a] to burning	Source
+,-	Daubenmire (1968)
-	Daubenmire (1968)
+	Vogl (1974)
-	Wright and Bailey (1982)
+	Wright and Bailey (1982)

o the results summarized here are not directly comparable with
greater biomass of vegetation, more flowering stalks, or
only to the conditions during the first growing season

sites; 0 = no difference between burned and unburned sites.

ss (*Agropyron smithii*) and blue grama (*Bouteloua gracilis*).

several studies, Adams and Anderson (1978) concluded that most studies that reported an increase in dry matter production following burning of native grasslands were done in the eastern tallgrass prairie where rainfall is relatively high. Results from the drier shortgrass prairie yielded less conclusive results. Although fire may improve production immediately following a burn, vigor generally declines as litter accumulates over time (Daubenmire 1968). In bluestem grasslands in the eastern part of the midcontinental grasslands, "...fire markedly increases production in the first postburn season, but within 2 to 3 years vigor has declined to the preburn level" (Daubenmire 1968:255). Litter accumulation in grasslands in the central to eastern United States generally returns to preburn levels within 2 to 6 years following burning (Daubenmire 1968). In Iowa, burning was considered to be beneficial to native prairie (via increased flowering of forbs, increased seedstalk production of native grasses, and control of introduced grasses), when litter accumulation approached the annual yield of vegetation (Ehrenreich and Aikman 1963). Similarly, Hulbert (1969) concluded that most literature indicates that litter removal increases grass growth only when litter is abundant. In shortgrass prairie, burning may increase herbage production if mulch accumulation is high, but may reduce yields due to heat kill, removal of growing points, crown exposure to temperature extremes, and unfavorable moisture relationships (Launchbaugh 1972). Wright and Bailey (1982:109) concluded that "...research results indicate no apparent benefits from burning herbaceous species in the arid mixed prairie where wheatgrasses predominate."

In terms of wildlife population response to fire, the most obvious effect to which wildlife species must respond following burning is a short-term dramatic change in habitat structure and local microclimate (Lyon et al. 1978). Burning has been found to be a useful management tool in maintaining prairie chicken (Tympanuchus cupido) habitat in Texas, although areas burned from fall through spring will generally not provide adequate habitat until the second postburn growing season (Chamrad and Dodd 1972). Burning grassland in Wind Cave National Park, South Dakota, had a detrimental effect on some birds and small mammals due to the reduced nesting cover (Forde 1983). Grasshopper sparrows (Ammodramus savannarum) and western meadowlarks (Sturnella neglecta) recovered to preburn levels within 2 to 3 years following burning, while upland sandpipers were barely recovered 3 years after burning. On the other hand, burning helped to create areas of sparse vegetation favored as lek sites by sharp-tailed grouse (Tympanuchus phasianellus). Prairie-chicken nest density was significantly greater on burned areas (1 nest/6 acres) than on unburned areas (1 nest/9.3 acres) in Illinois (Westemeier 1972). Reduced use of redtop (Agrostis alba) by prairie-chickens after the second or third growing season was due to the increased accumulation of litter, which promotes cool conditions during incubation, restricts movements, reduces food availability, and delays new plant growth. Insect abundance, a food source for many grassland nesting birds, was reduced 50% and 71% on two burned areas compared to controls (Forde et al. 1984). Indiscriminate annual burning is considered to reduce both the quantity and quality of nesting cover for blue-winged teal (Anas discors) (Fritzell 1975). Rotational burning at 3-year intervals was recommended as an effective management tool to maintain upland sandpiper nesting habitat (Kirsch and Higgins 1976). Nesting success and production of waterfowl in North Dakota was found to be greater on burned areas than on either undisturbed or grazed grassland; observations of sharp-tailed grouse broods were also higher on burned areas (Kirsch and Kruse 1973). Burning was considered to be the most effective tool to maintain the <40% cover preferred by sharp-tailed grouse (Miller 1963). The habitat structure, or vegetation profile, appropriate for a given bird species can be produced by burning, grazing, or mowing grasslands (Huber and Steuter 1984).

Maintenance and Management

Native grasses may be burned under a variety of frequency intervals. For example, Duebbert et al. (1981) recommended that burning be conducted at an interval of 5 to 10 years, although exact schedules must be defined on a site-specific basis. Kirsch and Higgins (1976) recommended rotational burning at 3-year intervals for effective management of upland sandpiper nesting habitat in North Dakota. Burning every 3 years in Illinois tallgrass prairie was recommended to maintain ideal prairie-chicken habitat (Westemeier 1972). In Wisconsin, burning once every 4 to 6 years was recommended to maintain maximum productivity, because ground layer vegetation reverted to preburn conditions during that time period (Vogl 1967).

Individual burns may vary considerably in size, from a few acres to several hundred acres. Preburn activities include development of a burning plan, firebreak mowing, and assemblage of equipment. Postburn activities include postburn evaluation and reporting. Once a burning program is instituted on an area, it is assumed that there will be no annual or periodic maintenance activities. However, the action will be repeated at prescribed intervals (i.e., the burning frequency).

Labor and Materials

Labor involved in burning native grasslands includes the preburn preparation (e.g., development of a burning plan, firebreak mowing, preliminary vegetation survey), the actual control of the burn, and the postburn evaluation and reporting.

Costs for burning vary, but the unit cost generally decreases as the size of the burn increases (Vogl 1967). Costs of burning brush prairie savannah in northwestern Wisconsin averaged $0.68/acre (1967 dollars) and ranged from $0.05 to $8.30/acre. Table 4.2 lists the cost items developed from the Garrison Diversion Unit study. Total development costs are estimated to be $325.00 to burn 200 acres using one field crew, for a unit costs of $1.63/acre. The costs are development costs only, which will be repeated at a prescribed frequency.

Table 4.2. Cost categories and estimated costs for burning native grassland.[a]

Cost categories[b]	Cost
Preburn preparation (6 work-hours @ approximately $8/hour)	$ 50.00
Field crew for burn control (18 work-hours)	200.00
Materials	25.00
Postburn evaluation and reporting (4 work-hours @ approximately $12.50/hour)	50.00
Total	$325.00
Cost/acre	1.63

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

[b] Activities and costs are based on a burn of 200 acres requiring one field crew.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Burning of native grassland is, by definition, restricted to native grassland. Unless a burning management program is intended to apply to all available native grasslands, it will be efficient to separate the area of unburned native grassland from burned native grassland. Futhermore, if a burning program uses different burning frequencies, then it will be necessary to separate grasslands under a given burning frequency from those under different frequencies. This is necessary because the effects on vegetation and, therefore, habitat variables, will be different under each different burning frequency.

Minimum management area. Any size area of native grassland can be burned, although the unit cost of burning is generally higher on smaller tracts of grassland. For purposes of this model, it is assumed that native grasslands must be ≥1 acre in order to use burning as a management tool.

Model Description

Overview. Burning of native grasslands causes dramatic changes in the physical structure of the habitat by removing dead vegetation (litter) and changing the local microclimate. However, the immediate changes resulting from fire do not maintain themselves over time. Therefore, habitat conditions will not be constant over time following burning. The habitat variables that are assumed to change as a result of burning are listed in Table 4.3. The only variable in Table 4.3 that will change with a change in the area burned is the area of a specified nonwetland cover type. The other variables will change with burning, but the change is assumed to be the same within a cover type regardless of the area burned. They are included here to show a process of predicting relatively dramatic changes over a relatively short time period.

There are at least two ways that the change in habitat variables due to burning can be treated. The first is to project changes in the variable over the specified burning cycle and keep the annual variables separate for analysis, thus achieving a simulation of habitat change over time on an annual basis. The second approach is to determine an average annual value for the variable under specified burning frequencies. The latter approach will not allow analysis of year to year variation in habitat suitability for species inhabiting native grassland, but will be simpler to analyze by reducing the number of potential data sets to be analyzed to one. The initial process is the same in either case, i.e., the changes in habitat variables over the burning cycle must be estimated.

Table 4.3. Habitat variables of native grassland potentially affected by burning.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Area of specified nonwetland cover type (ACT_j)	X	X
Average visual obstruction measurement (VO)	X	X
Percent herbaceous canopy cover (HCC)	X	X
Proportion of herbaceous canopy that is grass (PHG)	X	X
Maximum height of grass canopy (HGC)	X	X

[a] Because burning causes dramatic change following by gradual return to preburn conditions, values of habitat variables generally undergo initial decrease followed by a gradual increase.

093

The variables that are potentially changed by burning of native grassland are discussed individually below.

Area of specified nonwetland cover type (ACT_j). The act of burning native grassland does not cause an obvious change from one cover type to another as does an action such as wetland construction or planting dense nesting cover. However, unless the intent is to place all available grasslands under the exact same burning program, it will be necessary to keep track of the area of native grassland burned under specified frequencies, as well as the area of unburned native grassland. This is necessary because the habitat conditions will presumably be different under the different burning cycles. In order to determine the habitat suitability for the selected species identified in the Introduction, it is necessary to keep track of the differences in habitat conditions resulting from different management actions. In the case of burning, different burning frequencies are different management actions, because both the costs and habitat conditions will be specific to a given burning frequency. Simple difference equations can be used to track the changes in unburned and burned native grassland (Equations 4.1 and 4.2, respectively).

$$ACT_2 = ACT_{2B} - ANGB \qquad (4.1)$$

where ACT_2 = the area of native grassland (nonwetland cover type 2) following a management action

ACT_{2B} = the area of native grassland (nonwetland cover type 2) prior to management

$ANGB$ = the area of native grassland burned under a variety of frequencies (this value is the sum of all native grasslands burned, including all burning frequencies)

$$ACT_{2b} = ACT_{2Bb} + ANGB_b \qquad (4.2)$$

where ACT_{2b} = the area of native grassland (nonwetland cover type 2) burned with a burning frequency of every b years (e.g., 6, 7, 8, or 9 years) following a management action

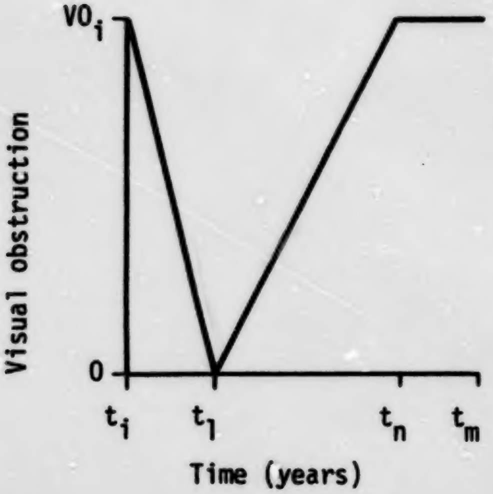
ACT_{2Bb} = the area of native grassland (nonwetland cover type 2) burned with a burning frequency of every b years prior to management

$ANGB_b$ = the area of native grassland placed under burning frequency b with management

099

Note that Equation 4.2 can be used with any number of burning frequencies, i.e., there will be as many equations of this form as there are burning frequencies selected in a given study.

Average visual obstruction measurement (VO). The visual obstruction measurement is estimated by viewing a round pole from a prespecified distance and determining how much of the pole is obscured by vegetation. The measurement may be taken at any time of the year, but the use of this variable in the habitat models discussed in the Introduction requires that such measurements be taken prior to spring growth of vegetation. The intent of this requirement is to estimate habitat conditions that exist at the time of nest initiation by migratory and resident birds. Burning has been found to increase vigor of growing vegetation in numerous studies, such that it can be reasonably concluded that the visual obstruction measurement taken during the growing season does increase with burning. However, the impact of burning on the visual obstruction measurement prior to spring growth is more difficult to determine. The immediate effect of burning in native grassland is to completely remove dead vegetation, thus creating a dramatic change in habitat structure. If the burn occurs outside of the growing season (i.e., fall through spring), it is most likely that no residual vegetation will be available in the spring prior to new growth. As vegetation grows during the years following a burn, the dead vegetation gradually accumulates to preburn conditions. Numerous studies indicate that litter accumulation returns to the preburn level within 2 to 6 years after burning and remains at that level indefinitely unless the site is again disturbed (Daubenmire 1968) by burning or some other means of litter removal. This general relationship is depicted in Figure 4.1, based on the



VO_i = visual obstruction measurement at t_i (prior to burning)

t_1 = the first spring following the burn

t_n = the time estimated for the visual obstruction measurement to return to pre-burn conditions

t_m = the last year prior to burning

Figure 4.1. An assumed response of the visual obstruction measurement to burning over one burning cycle.

assumption that the return to preburn conditions is linear. Figure 4.1 can be used to estimate annual values for the visual obstruction measurement (once local conditions are used to more precisely define the relationship), and these estimates can be used for annual estimates of habitat suitability. The simpler approach would be to use Figure 4.1 to estimate an average annual value for the variable so that only one data set is necessary in analyzing habitat suitability. The latter approach can be done with Equation 4.3, which requires annual estimates, or with Equation 4.4., which requires a subset of the annual estimates (the subset must include an estimate for the initial and ending year, t_1 and t_m in Figure 4.1).

$$XVO = \left[\sum_{\ell=1}^{m} VO_{\ell} \right] / m \qquad (4.3)$$

where XVO = the average annual visual obstruction measurement following a management action

VO_{ℓ} = the visual obstruction measurement at year ℓ

m = the period of analysis, i.e., the number of years between burns

$$XVO = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(VO_{2,\ell} + VO_{1,\ell})/2] \right] / m \qquad (4.4)$$

where XVO = the average annual visual obstruction measurement following a management action

t = the number of time intervals being evaluated (i.e., the number of selected years minus 1)

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

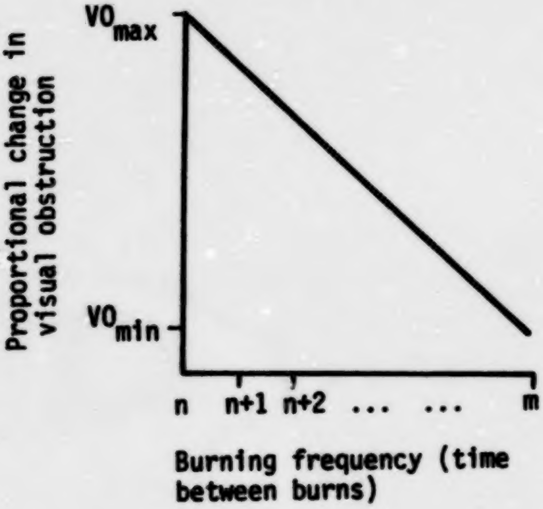
$VO_{1,\ell}$ = the estimated visual obstruction measurement at the beginning of time interval ℓ

$VO_{2,\ell}$ = the estimated visual obstruction measurement at the end of time interval ℓ

m = the period of analysis, i.e., the number of years between burns

It is obvious from the relationship depicted in Figure 4.1 that the average visual obstruction measurement is reduced over time as the result of burning. This relationship was based on information that the amount of litter returns to, and apparently does not exceed, preburn conditions following burning. Most of this information, however, was based on volume or weight of litter on burned plots compared to control plots, and the visual obstruction may not necessarily be related to the volume of litter. For example, this may not be the case if burning results in growth of more robust vegetation that either remains standing relatively upright, or that is resistant to flattening by snow. In such instances, the biomass of litter on burned and unburned plots may be the same, but the visual obstruction provided by the litter on the burned plots may be greater. There is some indication that new growth on burned sites stands more erect when dry (McCalla 1943, cited by Daubenmire 1968), suggesting that the visual obstruction measurement may actually increase over the burning cycle. Unfortunately, the available literature does not relate changes in litter following burning to visual obstruction, requiring that significant assumptions concerning changes due to fire be made in order to derive relationships such as that depicted in Figure 4.1.

Another approach to estimating the impacts of burning on the visual obstruction measurement in native grassland is to first estimate the maximum proportional change possible under burning (local experience may lend itself to deriving this estimate, even though such information does not appear to be available in the literature). For example, the maximum change in visual obstruction may be to increase the measurement by 5% of the preburn estimate. A corresponding burning cycle may then be defined. Increasing the burning cycle (e.g., from 6 to 9 years) may be assumed to cause a proportional decrease in the maximum gain, down to some minimum level for the longest burning cycle. This approach is depicted in Figure 4.2 and is the approach that was used in the analysis of burning on the Garrison Diversion Unit study. It has the advantages of being simple and requiring little in the way of hard information. It has the disadvantage of having little supporting information to defend the approach. If such an approach is taken, the average annual visual obstruction measurement to be expected under a given burning frequency can be determined with Equation 4.5, which adds the change in visual obstruction due to burning at a specified frequency to the visual obstruction existing prior to burning.



VO_{max} = the maximum proportional change in visual obstruction due to burning under the most desirable burning frequency

VO_{min} = the minimum proportional change in visual obstruction due to burning under the least desirable burning frequency

n = the burning frequency that produces VO_{max}

m = the burning frequency that produces VO_{min}

Figure 4.2. An assumed relationship between burning and the average annual change in the visual obstruction measurement.

$$XVO = VO_B + \left[\left[\left(\frac{VO_{max} - VO_{min}}{n-m}\right)f + b\right] \times VO_B\right] \qquad (4.5)$$

where XVO = the average annual visual obstruction measurement following a management action

VO_B = the visual obstruction measurement prior to management

VO_{max} = the maximum proportional change in visual obstruction due to burning under the most desirable burning frequency

VO_{min} = the minimum proportional change in visual obstruction due to burning under the least desirable burning frequency

n = the burning frequency that produces VO_{max}

m = the burning frequency that produces VO_{min}

f = the burning frequency selected for analysis

b = the y-intercept, equal to $VO_{max} - [(VO_{max} - VO_{min})/(n-m)]n$

Burning may improve habitat suitability for grassland birds in ways that are not measured by a visual obstruction measurement taken in early spring. For example, Schaffer et al. (1985) found that a visual obstruction measurement taken in late spring was a better predictor of nest density of gadwalls than an early spring measurement. Also, the earlier growth of vegetation on burned sites may provide nesting habitat without significant amounts of dead vegetation. Another improvement may be due to the reduced obstruction to movement at ground level, enabling broods to remain concealed while foraging or while moving between cover types (e.g., travel from nesting habitat to brood-rearing habitat).

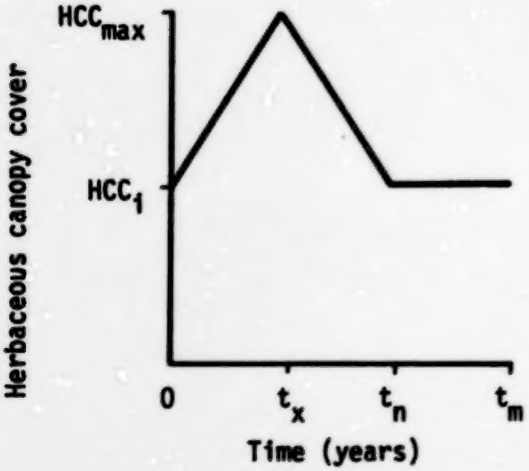
Percent herbaceous canopy cover (HCC). Burning performed in early spring has the immediate effect of removing dead vegetation. If conducted with local plants in mind, the burn can be made such that growing points of dormant vegetation are not damaged. Numerous studies report increased plant vigor following burns, either in height, number of flowering stalks, or general health. Although no study was found that specifically reported the impact of burning on herbaceous canopy cover, the numerous reports of increased production suggest an increase in this variable following burning. Logically, an increase may occur simply due to reduced competition for space resulting from the removal of dead vegetation. As litter accumulation returns to preburn conditions (as described above), herbaceous canopy cover can also be expected to return to preburn conditions, due to the increased occupation of space by dead vegetation. This relationship is depicted in Figure 4.3, and can be used to estimate changes in this variable using Equation 4.6 or 4.7.

$$XHCC = \left[\sum_{\ell=1}^{m} HCC_{\ell}\right]/m \qquad (4.6)$$

where XHCC = the average annual herbaceous canopy cover following a management action

HCC_{ℓ} = the herbaceous canopy cover at year ℓ

m = the period of analysis, i.e., the number of years between burns



HCC_{max} = maximum level of herbaceous canopy cover expected over the burning cycle

HCC_i = herbaceous canopy cover at year i (prior to burning)

t_i = the year prior to burning

t_x = the year at which HCC_{max} is expected to occur

t_n = the time estimated for herbaceous canopy cover to return to preburn conditions

t_m = the last year prior to burning

Figure 4.3. An assumed response of herbaceous canopy cover to burning over one burning cycle.

$$XHCC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(HCC_{2,\ell} + HCC_{1,\ell})/2]\right]/m \qquad (4.7)$$

where XHCC = the average annual herbaceous canopy cover following a management action

t = the number of time intervals being evaluated (i.e., the number of selected years minus one)

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$HCC_{1,\ell}$ = the estimated herbaceous canopy cover at the beginning of time interval ℓ

$HCC_{2,\ell}$ = the estimated herbaceous canopy cover at the end of time interval ℓ

m = the period of analysis, i.e., the number of years between burns

A simpler approach to estimating the change in herbaceous canopy cover due to burning is the same as described above for visual obstruction. A maximum proportional change in the average annual value of the variable may be estimated based on local expertise and a corresponding optimum burning frequency be defined. For example, it might be estimated that the average annual herbaceous canopy cover will increase by 10% of the original value (i.e., prior to burning) if burning is conducted every 6 years. The relative change resulting from longer burning cycles may be assumed to be linear down to some minimal change at the longest burning cycle (Figure 4.4). If this approach is taken, the average annual herbaceous canopy cover due to burning at a given frequency may be estimated with Equation 4.8, which adds the change due to burning to the value existing prior to burning.

$$XHCC = HCC_B + \left[\left[\left(\frac{HCC_{max} - HCC_{min}}{n - m} \right) f + b \right] \times HCC_B \right] \tag{4.8}$$

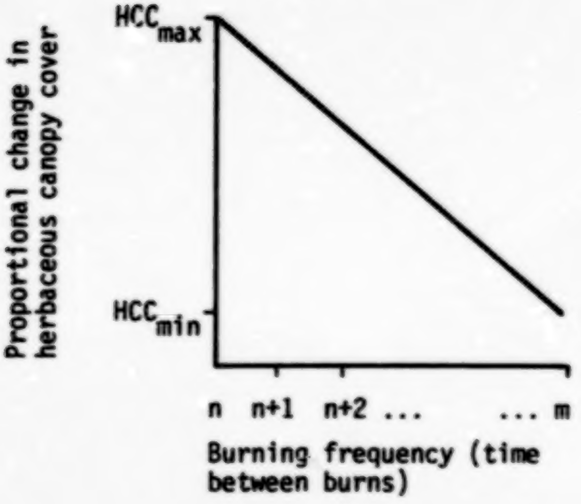
where $XHCC$ = the average annual herbaceous canopy cover following a management action

HCC_B = the herbaceous canopy cover prior to management

HCC_{max} = the maximum proportional change in herbaceous canopy cover due to burning under the most desirable burning frequency

HCC_{min} = the minimum proportional change in herbaceous canopy cover due to burning under the least desirable burning frequency

n = the burning frequency that produces HCC_{max}



HCC_{max} = the maximum proportional change in herbaceous canopy cover due to burning under the most desirable burning frequency

HCC_{min} = the minimum proportional change in herbaceous canopy cover due to burning under the least desirable burning frequency

n = the burning frequency that produces HCC_{max}

m = the burning frequency that produces HCC_{min}

Figure 4.4. An assumed relationship between burning and the average annual change in herbaceous canopy cover.

m = the burning frequency that produces HCC_{min}

f = the burning frequency selected for analysis

b = the y-intercept, equal to $HCC_{max} - [(HCC_{max} - HCC_{min})/(n-m)]n$

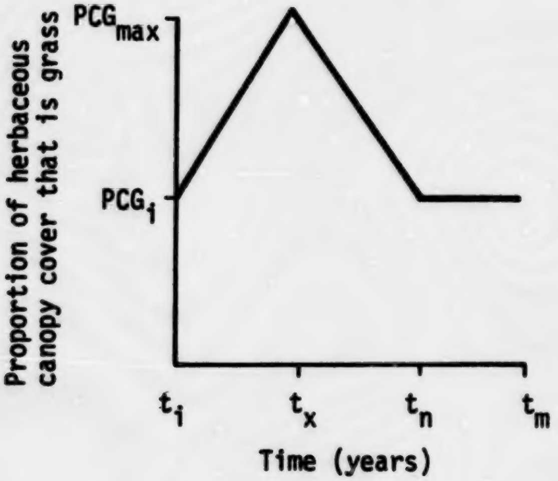
Proportion of herbaceous canopy that is grass (PCG). Very little information has been reported in the available literature concerning the quantitative change in proportion of grasses due to burning. However, several studies have reported changes in qualitative terms.

In Oklahoma, production of legumes and forbs was higher on burned sites than unburned sites, which suggests that the proportion of canopy cover contributed by grasses decreased with burning (Adams and Anderson 1978). Based on a summary of the available literature, Daubenmire (1968) concluded that burning favors forbs over grasses, both in perennial and annual grasslands. In contrast, both the biomass and frequency of grasses generally increased following burning in Ohio prairie, although similar results were not presented for forbs (Annala and Kapustka 1982). It is unclear whether the proportion of grasses in the canopy increased due to burning. In tallgrass prairie in Wisconsin, several grasses [e.g., little bluestem, big bluestem (Andropogon gerardi), and Indiangrass] and many forbs increased in frequency following burning (Anderson 1972). Again, it is unclear whether the proportion of grasses in the canopy actually changed, or if the relative proportion of grasses to forbs remained the same while the absolute canopy cover increased. Annual burning for 5 years in a Missouri prairie resulted in a complete dominance of grasses, burning every other year resulted in a mixture of grasses and broadleaved species, and burning every 5th year allowed forbs to increase in dominance over grasses (Kucera and Koelling 1964). Unburned plots resulted in decreased grass dominance.

In order to predict the effect of burning on the proportion of the herbaceous canopy that is contributed by grasses, it is necessary to estimate the effects over a selected burning cycle, as was done for visual obstruction and herbaceous canopy cover. Based on the results of Kucera and Koelling (1964), it is assumed that the initial response following burning is for grasses to increase in relative proportion and then decrease as the length of time between burns increases. If left unburned long enough, the proportion of herbaceous canopy that is grass will presumably resemble the unburned condition, i.e., conditions will return to preburn conditions. Given that litter accumulation is estimated to return to preburn conditions within 2 to 6 years after burning (Daubenmire 1968), it can be assumed that the species composition will also return to preburn conditions within 2 to 6 years following burning. This presumed relationship is depicted in Figure 4.5. An average annual value for the proportion of herbaceous canopy that is grass can be estimated by Equation 4.9 (using annual estimates) or Equation 4.10 (using selected target year estimates).

$$XPCG = \left[\sum_{\ell=1}^{m} PCG_{\ell} \right] / m \qquad (4.9)$$

where XPCG = the average annual proportion of herbaceous canopy cover that is grass following a management action



PCG_{max} = the maximum value achieved for the proportion of the herbaceous canopy cover that is grass due to burning compared to unburned conditions

PCG_i = the proportion of the herbaceous canopy cover that is grass prior to burning

t_i = the year prior to burning

t_x = the year at which PCG_{max} is reached

t_n = the time estimated for the proportion of the herbaceous canopy cover that is grass to return to preburn conditions

t_m = the last year of the burning cycle

Figure 4.5. An assumed response of the proportion of herbaceous canopy that is grass to burning over one burning cycle.

PCG_ℓ = the proportion of herbaceous canopy cover that is grass at year ℓ

m = the period of analysis, i.e., the number of years between burns

$$XPCG = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times \; [(PCG_{2,\ell} + PCG_{1,\ell})/2] \right] /m \qquad (4.10)$$

where $XPCG$ = the average annual proportion of herbaceous canopy cover that is grass following a management action

t = the number of time intervals being evaluated (i.e., the number of selected years minus one)

$T_{1,\ell}$ = the first target year of time interval ℓ

$T_{2,\ell}$ = the second target year of time interval ℓ

$PCG_{1,\ell}$ = the estimated proportion of herbaceous canopy cover that is grass at the beginning of time interval ℓ

$PCG_{2,\ell}$ = the estimated proportion of herbaceous canopy cover that is grass at the end of time interval ℓ

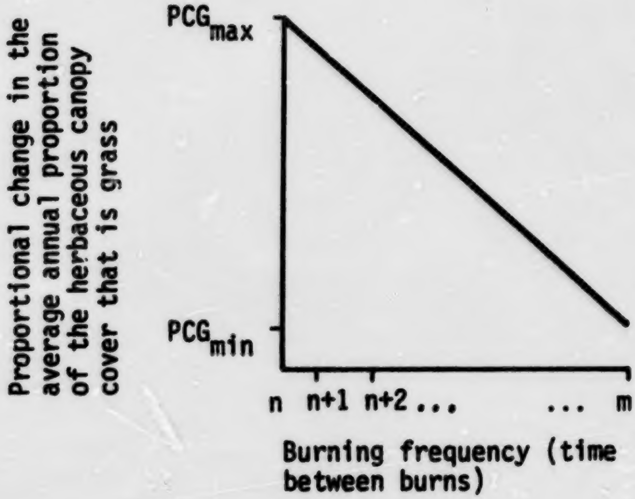
m = the period of analysis, i.e., the number of years between burns

As was suggested for the two preceding variables, a simpler approach to estimating the change in this variable due to burning is possible. A maximum proportional change in the average annual value of the variable may be estimated based on local expertise, and a corresponding optimum burning frequency can be defined. For example, it might be estimated that the average annual proportion of herbaceous canopy cover that is grass will increase by 10% of the original value (i.e., prior to burning) if burning is conducted every 6 years. The relative change resulting from longer burning cycles may be assumed to be linear down to some minimal change at the longest burning cycle (Figure 4.6). If this approach is taken, the average annual change in the proportion of the herbaceous canopy that is grass due to burning at a given frequency may be estimated with Equation 4.11, which adds the change due to burning to the value existing prior to burning.

$$XPCG = PCG_B + \left[\left[\left(\frac{PCG_{max} - PCG_{min}}{n - m} \right) f + b \right] \times PCG_B \right] \qquad (4.11)$$

where $XPCG$ = the average annual proportion of the herbaceous canopy that is grass following a management action

PCG_B = the proportion of the herbaceous canopy that is grass prior to management



PCG_{max} = the maximum proportional change in the proportion of herbaceous canopy cover that is grass due to burning under the most desirable burning frequency

PCG_{min} = the minimum proportional change in the proportion of herbaceous canopy cover that is grass due to burning under the least desirable burning frequency

n = the burning frequency that produces PCG_{max}

m = the burning frequency that produces PCG_{min}

Figure 4.6. An assumed relationship between burning and the proportional change in the proportion of the herbaceous canopy cover that is grass.

PCG_{max} = the maximum proportional change in the proportion of herbaceous canopy cover that is grass due to burning under the most desirable burning frequency

PCG_{min} = the minimum proportional change in the proportion of herbaceous canopy cover that is grass due to burning under the least desirable burning frequency

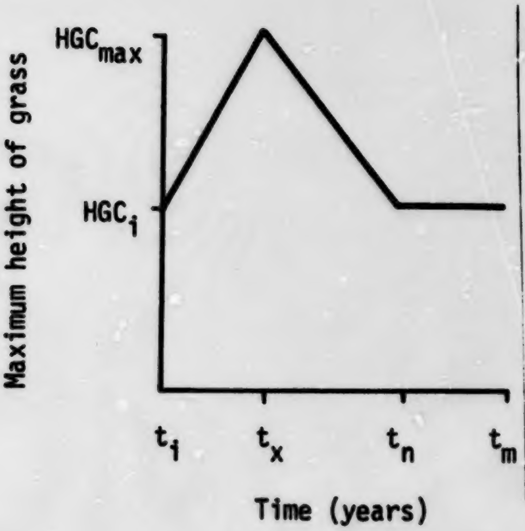
n = the burning frequency that produces PCG_{max}

m = the burning frequency that produces PCG_{min}

f = the burning frequency selected for analysis

b = the y-intercept, equal to $PCG_{max} - [(PCG_{max} - PCG_{min})/(n-m)]n$

Maximum height of grass canopy (HGC). Most investigations of the effects of burning on vegetation have concentrated on production of vegetation, number of stems, or number of flowering stalks. Hulbert (1969) reported that the height of bluegrass tillers on denuded plots (burning; clipping and removal; clipping, burning, and return of ash) ranged from 1.5 to 2.7 times the height of tillers on control plots. Other studies have indicated a change in dominance of individual species of grasses in response to burning. For example, midsummer burning can favor annual grasses over perennial bunchgrasses (Wright and Klemmedson 1965, cited by Forde et al. 1984), and warm-season grasses are favored by spring burns over cool-season grasses (such as Kentucky bluegrass). Since the growth form of different species of grasses differs, it is conceivable that burning can cause a change in the maximum height of the grass canopy. A presumed relationship between burning and height of the grass canopy is that grass height increases following burning, but decreases to preburn conditions within 2 to 6 years following burning (Figure 4.7). The decrease to preburn conditions is based on statements in the literature that refer specifically to production and species composition rather than to grass height. However, it is reasonable to assume that the return to preburn conditions includes the maximum height of the grass canopy. An average annual value for the maximum height of the grass canopy can be estimated with Equation 4.12 (using annual estimates) or Equation 4.13 (using selected target year estimates).



HGC_{max} = the maximum value for the maximum height of the grass canopy following burning

HGC_i = the maximum height of the grass canopy prior to burning

t_i = the year prior to burning

t_x = the year at which HGC_{max} is reached

t_n = the time estimated for the maximum height of the grass canopy to return to pre-burn conditions

t_m = the last year in the burning cycle

Figure 4.7. An assumed response of the maximum height of the grass canopy to burning over one burning cycle.

$$XHGC = \left[\sum_{\ell=1}^{m} HGC_{\ell} \right] / m \qquad (4.12)$$

where XHGC = the average annual maximum height of the grass canopy following a management action

HGC_{ℓ} = the maximum height of the grass canopy in year ℓ

m = the period of analysis, i.e., the number of years between burns

$$XHGC = \left[\sum_{\ell=1}^{t} (T_{2,\ell} - T_{1,\ell}) \times [(HGC_{1,\ell} + HGC_{2,\ell})/2] \right] / m \qquad (4.13)$$

where XHGC = the average annual maximum height of the grass canopy following a management action

t = the number of time intervals being evaluated (i.e., the number of selected years minus one)

$T_{1,\ell}$ = the first target year of time interval ℓ

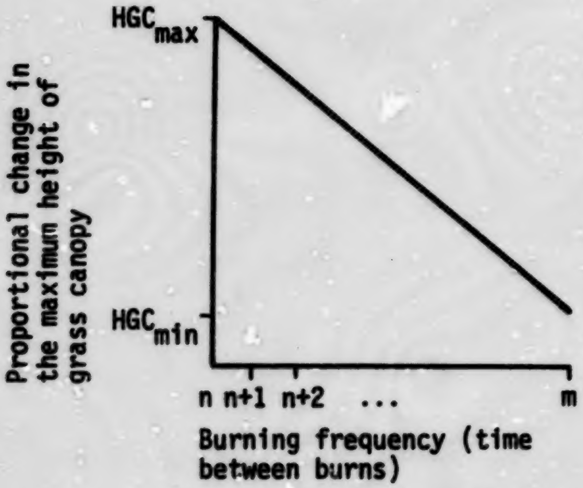
$T_{2,\ell}$ = the second target year of time interval ℓ

$HGC_{1,\ell}$ = the estimated maximum height of the grass canopy at the beginning of time interval ℓ

$HGC_{2,\ell}$ = the estimated maximum height of the grass canopy at the end of time interval ℓ

m = the period of analysis, i.e., the number of years between burns

As was suggested for the preceding variables, a simpler approach to estimating the change in this variable due to burning is possible. A maximum proportional change in the average annual value of the variable may be estimated based on local expertise and a corresponding optimum burning frequency can be defined. For example, it might be estimated that the average annual maximum height of the grass canopy will increase by 10% of the original value (i.e., prior to burning) if burning is conducted every 6 years. The relative change resulting from longer burning cycles may be assumed to be linear down to some minimal change at the longest burning cycle (Figure 4.8). If this approach is taken, the average annual change in the maximum height of the grass canopy due to burning at a given frequency may be estimated with Equation 4.14, which adds the change due to burning to the value existing prior to burning.



HGC_{max} = the maximum proportional change in the maximum height of the grass canopy due to under the most desirable burning frequency

HGC_{min} = the minimum proportional change in the maximum height of the grass canopy under the least desirable burning frequency

n = the burning frequency that produces HGC_{max}

m = the burning frequency that produces HGC_{min}

Figure 4.8. An assumed relationship between burning and the proportional change in the maximum height of the grass canopy.

$$XHGC = HGC_B + \left[\left[\left(\frac{HGC_{max} - HGC_{min}}{n - m} \right) f + b \right] x \; HGC_B \right] \qquad (4.14)$$

where XHGC = the average annual value for the maximum height of the grass canopy following a management action

HGC_B = the maximum height of the grass canopy prior to management

HGC_{max} = the maximum proportional change in the maximum height of the grass canopy due to burning under the most desirable burning frequency

HGC_{min} = the minimum proportional change in the maximum height of the grass canopy due to burning under the least desirable burning frequency

n = the burning frequency that produces HGC_{max}

m = the burning frequency that produces HGC_{min}

f = the burning frequency selected for analysis

b = the y-intercept, equal to $HGC_{max} - [(HGC_{max} - HGC_{min})/(n-m)]n$

Model Relationships

The presumed relationships between burning native grasslands and a number of habitat variables were described in the preceding section. Table 4.4 presents a summary of the variables discussed in the model and a reference to the equation(s) where each relationship is described. Many of the equations (Equations 4.3, 4.4, 4.6, 4.7, 4.9, 4.10, 4.12, and 4.13) simply provide a means of calcualting an average annual value for a given variable. This value will not necessarily change as the units of the action (e.g., number of hectares to be burned) change. The only variables that change as a function of the area burned are the area of the unburned native grassland and the area of the burned native grassland by burning frequency. Values for the remaining variables will vary with the selected burning frequency, but not with the amount of area burned.

Table 4.4. A summary of the habitat variables potentially affected by burning in native grassland.

Habitat variable (acronym)	Equation(s)	Page(s)
Area of specified nonwetland cover type (ACT_j)	4.1, 4.2	4.9
Average visual obstruction measurement (VO)	4.3, 4.4, 4.5	4.11, 4.13
Percent herbaceous canopy cover (HCC)	4.6, 4.7, 4.8	4.14, 4.15, 4.16
Proportion of herbaceous canopy that is grass (PCG)	4.9, 4.10, 4.11	4.18, 4.19, 4.20
Maximum height of grass canopy (HGC)	4.12, 4.13, 4.14	4.23, 4.25

Application of the Model

This model can be used to evaluate the influence of burning native grassland on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, requiring only that the user provide site-specific information prior to using the equations. The information that must be provided by the user is as follows.

1. Baseline conditions for all variables.

2. Prediction of maximum values attained by the variables following burning, but prior to a return to preburn conditions and an estimate of the time (i.e., years after burning) at which such values occur.

3. An estimate of the time required for the characteristics of burned native grassland to return to the preburn conditions.

4. An estimate of the minimum and maximum proportional changes to be expected in the habitat variables as a result of burning (necessary if the relationships expressed in Equations 4.5, 4.8, 4.11, and 4.14 are to be used); and an estimate of the burning frequencies that result in the minimum and maximum proportional changes.

LITERATURE CITED

Adams, D.E., and R.C. Anderson. 1978. The response of a central Oklahoma grassland to burning. Southwestern Nat. 23(4):623-632.

Aldous, A.E. 1934. Effect of burning on Kansas bluestem pastures. Kansas Agric. Exp. Sta. Tech. Bull. 38:1-65.

Anderson, K.L., E.F. Smith, and C.E. Owensby. 1970. Burning bluestem range. J. Range Manage. 23(1):81-92.

Anderson, R.C. 1972. The use of fire as a management tool on the Curtis Prairie. Proc. Tall Timbers Fire Ecol. Conf. 12:23-35.

Annala, A.E., and L.A. Kapustka. 1982. The microbial and vegetational response to fire in the Lynx Prairie Preserve, Adams County, Ohio. Prairie Nat. 14(4):101-112.

Cannode, C.L. 1965. Influence of cultural treatments on seed production of intermediate wheatgrass (Agropyron intermedium [Host] Bauv.). Agronomy J. 57(2):207-210.

Chamrad, A.D., and J.D. Dodd. 1972. Prescribed burning and grazing for prairie chicken habitat manipulation in the Texas Coastal Prairie. Proc. Tall Timbers Fire Ecol. Conf. 12:257-276.

Daubenmire, R. 1968. Ecology of fire in grasslands. Advances in Ecological Research 5:209-266.

Dix, R.L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology 41(1):49-56.

Duebbert, H.F., E.T. Jacobson, K.F. Higgins, and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the Prairie Pothole Region. U.S Fish Wildl. Serv. Spec. Sci. Rep. Wildlife 234. 21 pp.

Ehrenreich, J.H., and J.D. Aikman. 1963. An ecological study of the effect of certain management practices on native prairie in Iowa. Ecol. Monogr. 33(2):113-130.

Forde, J.D. 1983. The effect of fire on bird and small mammal communities in the grasslands of Wind Cave National Park. M.S. Thesis. Michigan Tech. Univ., Houghton. 140 pp.

Forde, J.D., N.F. Sloan, and D.A. Sloan. 1984. Grassland habitat management using prescribed burning in Wind Cave National Park, South Dakota. Prairie Nat. 16(3):97-110.

Fritzell, E.K. 1975. Effects of agricultural burning on nesting waterfowl. Can. Field-Nat. 89(1):21-27.

117

Gartner, F.R., and W.W. Thompson. 1972. Fire in the Black Hills forest-grass ecotone. Proc. Tall Timbers Fire Ecol. Conf. 12:37-68.

Hadley, E.B., and B.J. Kieckhefer. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44(2):389-395.

Hensel, R.L. 1923. Effect of burning on vegetation in Kansas pastures. J. Agric. Res. 23:631-644.

Hopkins, H.H., F.W. Albertson, and A. Riegel. 1948. Some effects of burning upon a prairie in west-central Kansas. Trans. Kansas Acad. Sci. 51:131-141.

Huber G.E., and A.A. Steuter. 1984. Vegetation profile and grassland bird response to spring burning. Prairie Nat. 16(2):55-61.

Hulbert, L.C. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. Ecology 50(5):874-877.

Kirsch, L.M., and K. F. Higgins. 1976. Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4(1):16-20.

Kirsch, L.M., and A.D. Kruse. 1973. Prairie fires and wildlife. Proc. Tall Timbers Fire Ecol. Conf. 12:289-303.

Kucera, C.L., and J.H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology 43(2):334-336.

Kucera, C.L., and M. Koelling. 1964. The influence of fire on composition of central Missouri prairie. Am. Midl. Nat. 72(1):142-147.

Launchbaugh, J.L. 1964. Effects of early spring burning on yields of native vegetation. J. Range Manage. 17(1):5-6.

______________. 1972. Effect of fire on shortgrass and mixed prairie species. Proc. Tall Timbers Fire Ecol. Conf. 12:129-151.

Lyon, L.J., H.S. Crawford, E. Czuhai, R.L. Fredricksen, L.J. Metz, and H.A. Pearson. 1978. Effects of fire on fauna: a state-of-knowledge review. U.S. For. Serv. Gen. Tech. Rep. WO-6. 41 pp.

McCalla, T.M. 1943. Microbiological studies of the effect of straw used as a mulch. Trans. Kansas Acad. Sci. 43:52-56. [Cited by Daubenmire 1968.]

Miller, H.A. 1963. Use of fire in wildlife management. Proc. Tall Timbers Fire Ecol. Conf. 2:19-30.

Peet, M.M. 1971. The effect of burning on microclimate and production in Wisconsin tall-grass prairie. M.S. Thesis. Univ. Wisconsin, Madison. 125 pp.

Rice, E.L., and R.L. Parenti. 1978. Causes of decreases in productivity in undisturbed tall grass prairie. Am. J. Bot. 65(10):1091-1097.

Rothermal, R.C., and J.E. Deeming. 1980. Measuring and interpreting fire behavior for correlation with fire effects. U.S. For. Serv. Gen. Tech. Rep. INT-93. 4 pp.

Scheffer, T.L., J.T. Lokemoen, and D.H. Johnson. 1985. Relations between blue-winged teal and gadwall nest densities and habitat features. U.S. Fish Wildl. Serv., Northern Prairie Wildlife Research Center, report to Western Energy and Land Use Team, Fort Collins, CO. 23 pp.

Schlichtemeier, G. 1967. Marsh burning for waterfowl. Proc. Tall Timbers Fire Ecol. Conf. 6:41-46.

Smith, E.F., and C.E. Owensby. 1972. Effects of fire on true prairie grasslands. Proc. Tall Timbers Fire Ecol. Conf. 12:9-22.

Vogl, R.J. 1967. Controlled burning for wildlife in Wisconsin. Proc. Tall Timbers Fire Ecol. Conf. 6:47-96.

____________. 1974. Effects of fire on grasslands. Pages 139-194 in T.T. Kozlowski and C.E. Ahlgren, eds. Fire and ecosystems. Academic Press, New York.

Westemeier, R.L. 1972. Prescribed burning in grassland management for prairie chickens in Illinois. Proc. Tall Timbers Fire Ecol. Conf. 12:317-338.

Wright, H.A. 1974a. Range burning. J. Range Manage. 27(1):5-11.

____________. 1974b. Effect of fire on southern mixed prairie grasses. J. Range Manage. 27(6):417-419.

Wright, H.A., and A.W. Bailey. 1982. Fire ecology: United States and southern Canada. John Wiley and Sons, New York. 501 pp.

Wright, H.A., and J.O. Klemmedson. 1965. Effects of fire on bunchgrasses of the sagebrush-grass region of southern Idaho. Ecology 46:680-688. [Cited by Forde et al. 1984.]

5. UPLAND VEGETATION PROTECTION
a. Grazing control

MANAGEMENT ACTION INFORMATION

Purpose

The purpose of grazing control is to manipulate vegetation to a desired condition. From a wildlife management perspective, the purpose may be to maximize the amount of available cover during the breeding season. From a rancher's perspective, the purpose may be to maximize the amount of sustainable forage. Approaches to grazing control from a wildlife management perspective are generally of two types. The first is to control the extent of grazing by manipulating the amount, timing, and duration of grazing. The second is to totally exclude grazing from a given area; this approach is simply a special case of the first approach. This discussion will review literature from both types of approaches and the Management Action Model section will also present methods of quantifying changes in habitat variables resulting from the two approaches.

Effects of Management Action

The effects of grazing are primarily on vegetation and soils of a grazed area. Effects may be apparent in vegetative cover, diversity, structural complexity, composition, and soil structure. The extent and significance of impacts depends upon a number of factors, including the timing, duration, and extent of grazing, and past land use history. The amount of variation in grazing systems makes the assessment of impacts to wildlife difficult. Kirsch et al. (1978:486) noted that the "relationships of grazing to wildlife populations are difficult to define because grazing often varies so much in intensity, time, and distribution." The following discussion will concentrate on studies of grazing that have been conducted from a wildlife perspective; no attempt has been made to incorporate the vast amount of literature available on grazing from a range management or animal husbandry perspective.

Several authors have related observed negative impacts of grazing on wildlife to the reduction of residual vegetation, i.e., vegetation that is available early in the spring. Tall and dense residual vegetation is important for nesting by waterfowl (Bue et al. 1952; Kirsch et al. 1978; Ruyle et al. 1980), upland game birds, and some nongame birds (Kirsch et al. 1978). In Montana, numbers of male sharp-tailed grouse on breeding grounds increased in 14 of 15 instances where residual cover was increased, and decreased in 16 of 20 instances where residual cover was decreased (Brown 1966). Furthermore, the largest breeding grounds were surrounded by extensive stands of heavy residual vegetation. The main direct effect of grazing on sharp-tailed grouse habitat is the reduction of residual cover, although such negative effects primarily result from intensive grazing (Kessler and Bosch 1982). Waterfowl production will generally be reduced by any activity, such as grazing or mowing, that reduces the amount of residual cover (Kirsch 1969). Waterfowl nesting success has been observed to be higher in fields that provide the tallest, most dense vegetation (Kirsch et al. 1978). Waterfowl pair populations, nest densities, and nesting success in North Dakota grasslands were all higher on ungrazed areas compared to lightly, moderately, and heavily grazed areas (Kirsch 1969).

Avian species richness in North Dakota native grasslands tended to increase with increasing grazing intensity, although average total bird density was higher on heavily grazed plots due to increased dominance by a few species (Kantrud 1981). Heavily grazed grasslands supported 22 bird species, moderately grazed areas supported 26 bird species, and lightly grazed grasslands supported 27 bird species (grazing intensity levels were subjective categories). In Arizona, Bock et al. (1984) found that grazed areas supported significantly higher numbers of birds in summer than ungrazed areas, even though the ungrazed area supported 45% more grass cover, a relatively heterogenous grass community, and significantly more herb cover. The higher numbers of birds observed on the grazed area was attributed to occupancy of the site by birds characteristic of lower elevation, more xeric, habitats.

Although "...bird species do not respond to grazing per se, but to its effects on vegetation" (Bock and Webb 1984:1049), some loss due to trampling of nests has been reported (Gjersing 1975). Heavy grazing has been implicated as the cause of reduced wildlife production in several studies, but less certainty exists on the impacts of light and moderate grazing levels. Several studies have also discussed the use of grazing as a valuable management tool for improving or maintaining wildlife habitat in a high quality condition. For example, blue-winged teal nest density in South Dakota was observed to be highest (26.4 nests/km^2) on rangeland in excellent condition; excellent range can be achieved by "...proper use of burning, grazing, resting, and haying" (Kaiser et al. 1979:297). Light to moderate grazing may be beneficial to sharp-tailed grouse habitat (Kessler and Bosch 1982). Livestock concentration can create suitable courtship habitat for sharp-tailed grouse (i.e., short, sparse vegetation), but excessive grazing can reduce the amount of climax vegetation necessary for successful nesting and can also reduce shrub cover used by broods (Sisson 1976). Kirsch et al. (1978) recommended the elimination of annual grazing and mowing on native grasslands managed to provide attractive and secure nesting cover, but short-term heavy grazing can be used to restore grass vigor to maintain desired levels of residual vegetation. Native vegetation is adapted to recover from short-term periods of intensive use (Hillman and Jackson 1973). Grazing can also be used to create openings in dense stands of bulrush (Scirpus sp.) to provide open water for broods of diving ducks (Rees 1982).

The type of grazing system used may have a significant impact on the conditions available for wildlife. Cattle in an open grazing system in Montana removed 64% to 76% of the available forage during late fall and winter (Brown 1961), which resulted in a major reduction in the amount of residual vegetation available to wildlife the following spring. Pastures grazed in late summer and fall will have the least amount of residual vegetation available the following spring, whereas pastures grazed only in spring and early summer will allow for growth of vegetation and subsequent availability of residual vegetation (Gjersing 1975). Season-long grazing in a South Dakota study resulted in a significantly higher amount of residual vegetation (measured via a visual obstruction measurement) than did deferred-rotation grazing (Mattise et al. 1982). Season-long grazing resulted in lighter grazing over a larger area, whereas deferred-rotation grazing resulted in uniformly heavy grazing over a smaller area and a shorter period of time. Delayed grazing may be beneficial by reducing disturbance during the peak nesting period, by improving the vigor of cool-season grasses, and by allowing late summer/early fall growth of herbaceous vegetation (Ruyle et al. 1980).

Maintenance and Management

Grazing control requires the use of fences, whether the intent is to regulate the amount of grazing or to totally exclude livestock. The exception to this is in the system of continuous grazing on open range (Gray et al. 1982); the disadvantage of such a system is that the range is grazed unevenly, and the preferred livestock forage is overutilized. Implementation of other systems, such as deferred grazing, rotation grazing, rest grazing, or combination grazing (Gray et al. 1982), are most efficiently implemented where control is possible as the result of fences. Because fences are not permanent fixtures, they generally must be replaced over time and also require annual maintenance.

Labor and Material

Grazing control is an expensive management activity. Labor and materials include the fencing material, the labor to erect the fence, annual maintenance, and eventual replacement. Costs will vary with the type of fence erected. Construction costs for a 4-wire barbed fence were estimated at $8,100/mile on the Garrison Diversion Unit study, including administrative overhead, boundary surveys, and inspection during construction, in addition to the actual labor and materials involved in construction (Table 5.1). Annual maintenance costs were estimated to be $200/mile with replacement every 25 years. The total discounted cost (at 3-1/8% for 100 years) was estimated to be $6.23/acre. The discounted cost was based on six miles of fencing necessary to fence a section of land (640 acres) into quarter-sections. Estimated fencing cost on the Central Dakota project (U.S. Fish and Wildlife Service, Central Dakota project, unpublished file data), was $5,700/mile of fence with 2% annual operations and maintenance costs.

Estimates of total costs do not need to be made on a fixed configuration. Given the cost of fence per length (e.g., per mile), the total cost can be determined by using simple equations based on the geometric shape of the parcel to be fenced. For example, Equations 5.1 and 5.2 provide a means of determining the total length of fence and, therefore, the total cost, necessary for square and rectangular (of fixed width, w) areas, respectively.

Table 5.1. Estimated costs for fence construction and maintenance.[a]

Year	Activity	Cost/6-mile fence[b]	Cost/fenced acre[c]
1	Construction	48,600	$75.94
25	Replacement	48,600	75.94
75	Replacement	48,600	75.94
	Annual O&M	1,200	1.88

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Ft. Collins, CO. n.p.

[b] The need for six miles of fence per section is based on fencing a section (640 acres) into quarter sections to allow active management of the magnitude of grazing. If the goal is total exclusion of grazing, then internal fencing is unnecessary and total length of fence can be determined with Equations 5.1 and 5.2.

[c] These costs are not summed to a single total because the activities occur in different years. An appropriate discount factor based on a selected discount rate must be used to determine the present worth of each activity. For the Garrison Diversion Unit study, the average annual discounted cost was estimated to be $6.23, based on a discount rate of 3-1/8% and a 100-year period of analysis.

$$TLF = 4 \times \sqrt{A} \tag{5.1}$$

$$TLF = (2 \times w) + (2 \times \frac{A}{w}) \tag{5.2}$$

where TLF = the total length (in ft or m) of fence required to fence a given area

A = the area to be fenced (in ft^2 or m^2)

w = the width of a rectangular area to be fenced (in ft or m)

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Fencing to control grazing can be applied to virtually any cover type, including both upland and wetland types. In most instances, the cover types being protected from grazing via fencing will be tame or native grassland cover types, since these cover types are the ones typically grazed. Fencing a large block of a given cover type also typically protects other types from the impacts of grazing. For example, shelterbelts and wetlands may be included in the protected area even though the intent of the fencing is to protect a single specified cover type. In such cases, benefits of grazing control will apply to cover types other than the primary type being fenced. The equations presented in this model assume that only the specified cover type gains the benefits of the management action of grazing control.

Minimum management area. It is theoretically possible, although not usually practical, to control grazing on any size area. In typical applications, the minimum area being protected will be of relatively large size, perhaps on the order of 40 acres. However, for certain cover types that are highly valued from a wildlife perspective (e.g., shelterbelts, wetlands), fencing may occur on very small areas.

Model Description

Overview. This model describes the relationships between the action of grazing control and selected habitat variables (Table 5.2). Grazing control may be applied in one of two ways. The first is to control the amount of grazing, e.g., by controlling stocking rates and duration of grazing. The second is to totally exclude grazing. In the first instance, structural habitat variables are expected to respond to the level of grazing; the action is applied both by the grazing level and by the amount of area to be managed under a specified grazing system. In the second instance, only those variables that reflect the amount and distribution of cover types will be impacted, since the action will be applied simply by the area to be completely protected from grazing. Each of the variables potentially impacted by grazing control, either total exclusion or grazing management, are discussed in the following sections. It is assumed in this model that there will always be some level of grazing if the user chooses to vary the amount of grazing, i.e., total exclusion of livestock is considered as a separate action from control of the amount of grazing.

If the approach is to exclude grazing completely from the area, then average annual values must be estimated for the following variables over the assumed life of the project in order to evaluate the six wildlife species identified in the Introduction: (1) average visual obstruction measurement, (2) percent herbaceous canopy cover, (3) proportion of herbaceous canopy that is grass, and (4) maximum height of grass canopy.

Table 5.2. Habitat variables potentially affected by grazing control.[a]

Habitat variable (acronym)	Direction of change[b]	
	Increase	Decrease
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)	X	
Distribution of idle cover (DIC)	X	
Average visual obstruction measurement (VO)	X	
Percent herbaceous canopy cover (HCC)	X	
Proportion of herbaceous canopy cover that is grass (HCG)	X	
Distance to a wetland ≥0.4 ha (DW)	X	X
Maximum height of grass canopy (HGC)	X	

[a] Variables VO, HCC, HCG, and HGC will only vary with different levels of grazing control if the action is to control the amount of grazing rather than the total exclusion of grazing.

[b] The direction of change refers to the most likely difference in the quantity of a variable as a result of grazing control. Variables for which both a positive and negative change are indicated are the result of changes in different cover types.

Area of specified nonwetland cover type (ACT_j). Grazing control, whether by total exclusion or by management of grazing, will presumably create cover types that are structurally different than those that existed prior to management. Although grazing management does not change the general cover type classification (e.g., a tame grassland prior to grazing management is a tame grassland following grazing management), it does create a different habitat than existed prior to management. Unless the intent is to implement the exact same grazing management on all available areas of a given cover type, it will be necessary to keep separate the areas under various grazing management systems in order to account for the possible differences in habitat quality as the result of management. Simple difference equations can be used to track the changes in unmanaged and managed (perhaps by more than one grazing system) cover types (Equations 5.3 and 5.4, respectively).

$$ACT_j = ACT_{jB} - ACTG \qquad (5.3)$$

where ACT_j = the area of cover type j following a management action

ACT_{jB} = the area of cover type j prior to management

$ACTG$ = the area of cover type j put under grazing management (this value is the sum of all areas of the cover type that are placed under grazing management, regardless of grazing system)

$$ACT_{jg} = ACT_{jBg} + ACTG_{jg} \qquad (5.4)$$

where ACT_{jg} = the area of cover type j under grazing management system g

ACT_{jBg} = the area of cover type j under grazing management system g prior to management

$ACTG_{jg}$ = the area of cover type j placed under grazing system g with management

Note that Equation 5.4 can be used with any number of grazing systems, i.e., there will be as many equations of this form as there are grazing systems.

Percent of area in pasture/hayland (PPH). This variable will only be affected by the grazing control management action if the approach to grazing management is to totally exclude livestock. In such a situation, areas that were previously subject to grazing will be removed from grazing, thus changing the relative proportion of the area used for pasture/hayland. In theory, it is also possible to change this variable by allowing grazing on areas that were previously ungrazed. However, it is considered unlikely that this action will take place for wildlife management purposes, except as a short-term approach to restoring the vigor of grasses. Equation 5.5 describes the relationship between the area removed from grazing and the percent of the area in pasture/hayland.

$$PPH = \left[\frac{APH_B - ARG}{\text{Total study area}} \right] \times 100 \qquad (5.5)$$

where PPH = percent of an area in pasture/hayland land uses following a management action

APH_B = the area of pasture/hayland prior to management

ARG = the area of pasture/hayland removed from grazing as the result of management

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types. As with the percent of the area in pasture/hayland, this variable will only change as the result of grazing management if the option is total exclusion of grazing from areas that were previously grazed. Grazing management that manages the amount of grazing (but where grazing is allowed) will not result in lands that meet the definition of idle land and, therefore, will not cause a change in this variable. It is assumed that grazing management by controlling the amount of grazing will never be implemented for wildlife management purposes on lands that are currently ungrazed (except for the occasional short-term use of grazing to restore grass vigor). Therefore, the only way that grazing management can influence this variable is by having more lands classified as idle as the result of total exclusion of livestock, as expressed in Equation 5.6.

$$PIL = \left[\frac{AIL_B + ARG}{\text{Total study area}} \right] \times 100 \qquad (5.6)$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

ARG = the area of pasture/hayland removed from grazing as the result of management

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km^2 sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed, and do not support crops. As with the preceding two variables, management of grazing by controlling the amount of grazing (other than total exclusion) will not have any effect on this variable because the conditions will still not meet the definition of idle cover. However, total exclusion of grazing will have an impact on this variable, presuming that exclusion takes place on areas that currently are grazed. A conservative estimate of the impact of grazing exclusion on this variable is to increase the number of idle grids by one for every 4 ha planted. This is a conservative estimate because grids are also classified as idle if they border idle cover in an adjacent grid. Every 4 ha protected from grazing may change three to five grids to an idle classification (Figure 5.1). An example on a larger scale, in which fencing for grazing control will usually be applied, is presented in Figure 5.2, in which all 64 grids can be changed to an idle classification by actually fencing around only 49 of the square grids. Hypothetical applications of this management action on a study area map can be used to determine the actual ratio between area excluded from grazing and the number of idle 4 ha grid cells. In order to be most effective, the ratio should be determined for each application of the management action, although a fixed ratio will be easier to use. Equation 5.7 presents the simplest, most conservative, case where each 4 ha converted to native grassland increases the number of grid cells with idle cover by one.

$$DIC = NGIL_B + \left[\frac{ARG}{4} \times \frac{259}{\text{Total study area (ha)}} \right] \qquad (5.7)$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells/$2.59\ \text{km}^2$ that contain or border idle cover following a management action

$NGIL_B$ = the number of 4-ha grid cells/$2.59\ \text{km}^2$ that contain or border idle cover prior to management

ARG = the area of pasture/hayland removed from grazing as the result of management

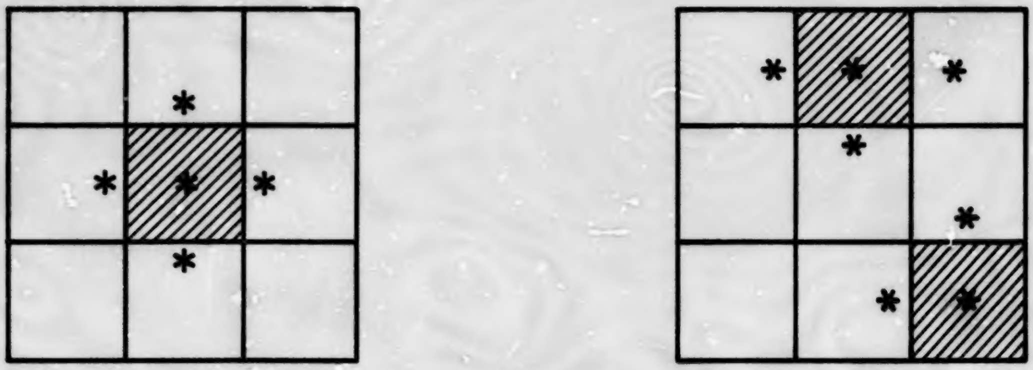


Figure 5.1. Examples of how the distribution of grazing exclusion changes the ratio of protected area to number of idle grid cells (shaded grid cells = 4 ha of protected area, * indicates grid cells classified as idle cover as a result; based on assumption of total grazing exclusion).

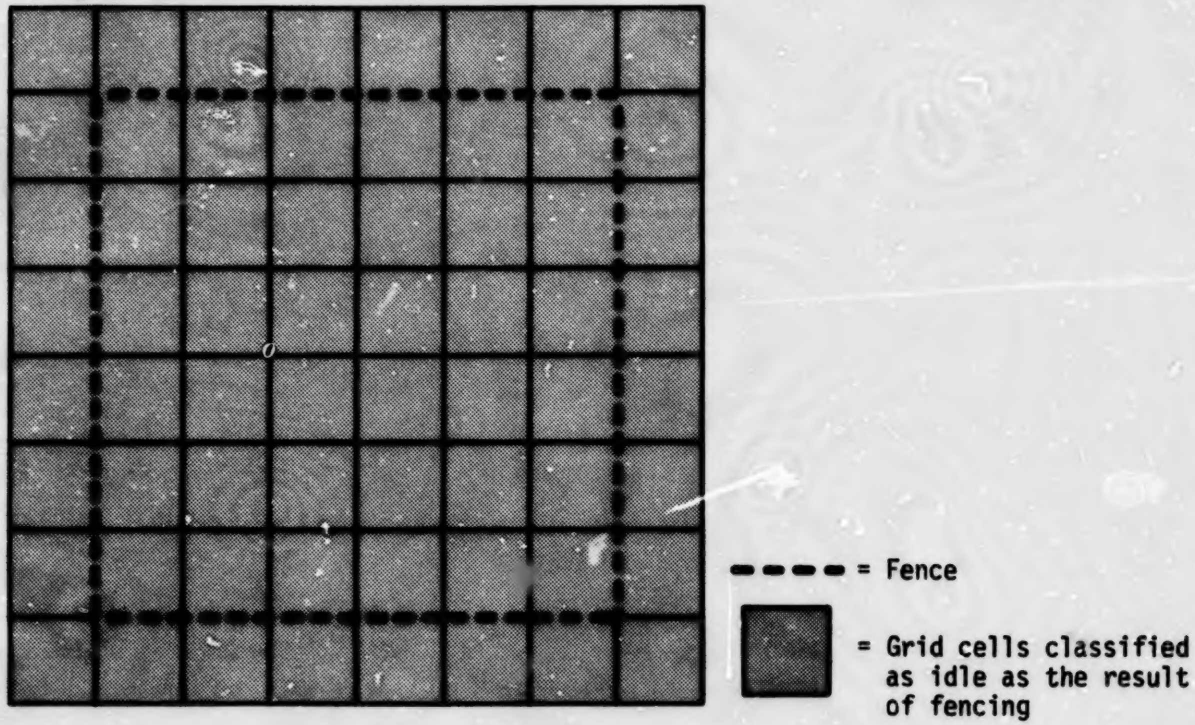
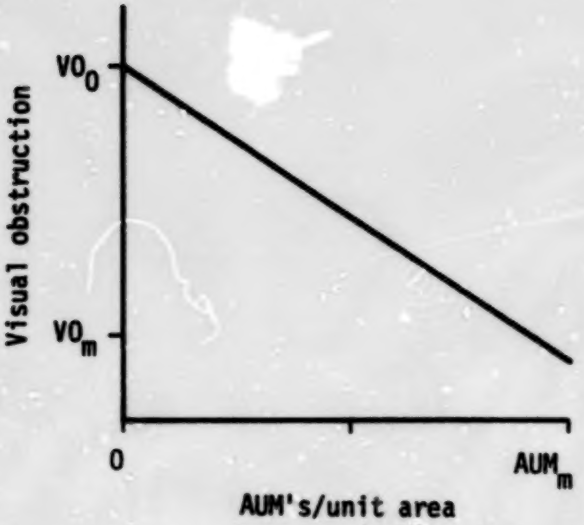

= Fence
= Grid cells classified as idle as the result of fencing

Figure 5.2. Example of a change in the number of grid cells/2.59 km² due to grazing exclusion on a large-scale basis.

Equation 5.7 produces an output in terms of the number of grid cells/ 2.59 km^2, based on excluding grazing in 4-ha increments. Since this is unrealistic except for small, highly valued, cover types, users are strongly encouraged to develop a more realistic ratio of protected area to number of idle grid cells before using Equation 5.7.

Average visual obstruction (VO). The visual obstruction measurement is estimated by viewing a round pole from a specified distance and determining how much of the pole is obscured by vegetation. The measurement may be taken at any time of the year, but the use of this variable in the habitat models discussed in the Introduction requires that such measurements be taken prior to spring growth of vegetation. The intent of this requirement is to estimate habitat conditions that exist at the time of nest initiation by migratory and resident birds. Grazing management that involves management of the amount, timing, and duration of grazing can have a significant impact on this variable. Grazing management that totally excludes grazing will cause a change in this variable, but this change will not vary with a change in the amount of area excluded from grazing. Certain responses (e.g., more residual vegetation) are expected by totally excluding livestock, but these responses are expected whether livestock are excluded from 1 ha or 1,000 ha. Since exclusion of livestock is applied in units of area protected, the only changes subsequent to exclusion will be the result of other environmental variables, such as soil and moisture conditions. If, however, the grazing management involves varying the amount of grazing, then the management action can have significant influence on the amount of residual vegetation.

A major difficulty in predicting the change in residual vegetation in response to a change in the amount of grazing lies in the inherent variability of various grazing recommendations. For example, the amount of grazing can be varied (generally in Animal Unit Months/unit area, or AUM's/unit area), the duration can be varied, and the seasonal timing can be varied. For purposes of this discussion, only variations in AUM's/unit area will be considered. Incorporation of all the variables involved in the response of vegetation to grazing would require a modeling effort far beyond the scope attempted here. Figure 5.3 shows a hypothetical relationship that can be used to determine the impact of varying the amount of grazing on this variable. The relationship is based on the premise that at least two points are known. One point is the estimated value of the variable if all livestock are removed (this value is an average annual value determined over the period of analysis). Presumably, this variable will be the maximum attainable based on the plant species composition since no significant amounts of vegetation are removed by grazing. The second known point is based on an observation of the existing visual obstruction measurement resulting from a known number of AUM's/unit area; in some cases, this observation may be at the other extreme from total exclusion, i.e., it may represent the maximum sustainable level of AUM's/unit area. Based on these two point estimates, the linear relationship depicted in Figure 5.3 can be assumed. Obviously, additional data points will help to better define the shape of the curve. Once the shape of the curve has been



VO_0 = the average visual obstruction measurement in the complete absence of grazing

VO_m = the average visual obstruction measurement at the maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

Figure 5.3. Assumed relationship between grazing intensity and the average visual obstruction measurement.

estimated, equations can be developed to estimate the value of the visual obstruction measurement for any level of AUM's/unit area. For example, Equation 5.8 provides the solution to the line depicted in Figure 5.3.

$$VO = \left[\frac{VO_m - VO_0}{AUM_m} \times AUM_i \right] + VO_0 \qquad (5.8)$$

where VO = the average visual obstruction measurement following a management action

VO_0 = the average visual obstruction measurement in the complete absence of grazing

VO_m = the average visual obstruction measurement at the maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

AUM_i = the grazing intensity, measured in AUM's/unit area, to be implemented by management

Percent herbaceous canopy cover (HCC). Herbaceous canopy cover is presumably reduced by any appreciable amount of grazing. The pertinent question is how the reduction relates to grazing intensity. Based on the simple assumption that there is a linear inverse relationship between herbaceous canopy cover and grazing intensity, the relationship depicted in Figure 5.4 can be developed. Equation 5.9 can be used to determine a value for herbaceous canopy cover for any level of grazing intensity, based on the linear relationship in Figure 5.4.

$$HCC = \left[\frac{HCC_m - HCC_0}{AUM_m} \times AUM_i \right] + HCC_0 \qquad (5.9)$$

where HCC = the average percent herbaceous canopy cover following a management action

HCC_0 = the average percent herbaceous canopy cover in the complete absence of grazing

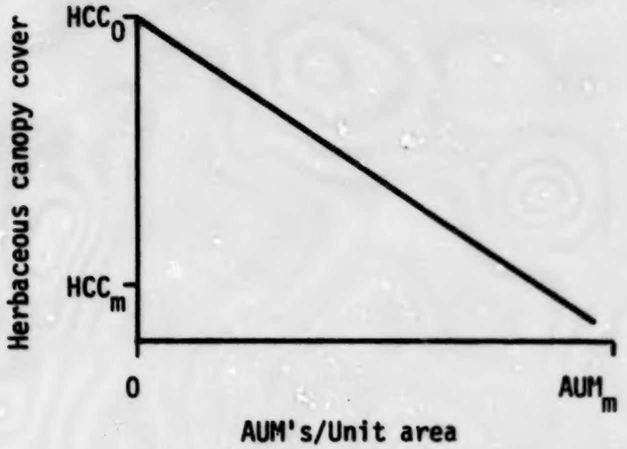
HCC_m = the average percent herbaceous canopy cover at the maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

AUM_i = the grazing intensity, measured in AUM's/unit area, to be implemented by management

Figure 5.4 and Equation 5.9 present a very simplified relationship between grazing and herbaceous canopy cover. In all likelihood, the relationship is not nearly as simple as presented here. Besides the obvious factors of grazing duration and timing, other factors, such as plant species composition, plant palatability, moisture conditions, and soil conditions, influence the actual relationship. Users with more pertinent data to support a different relationship between grazing and herbaceous cover are encouraged to do so; otherwise, the relationships depicted here will probably suffice.

Proportion of herbaceous canopy cover that is grass (HCG). As with the preceding variable, this variable will only change with changes in grazing management if the management action involves varying the amount of grazing. Little information was found in the literature to comfortably describe the relationship between grass canopy cover and grazing. If grazing is distributed among plants according to their relative abundance, then the relationship described for this variable will be exactly the same as for percent herbaceous canopy cover described above. However, if grazing is not evenly distributed across all plants (e.g., as the result of palatability), then the relationship



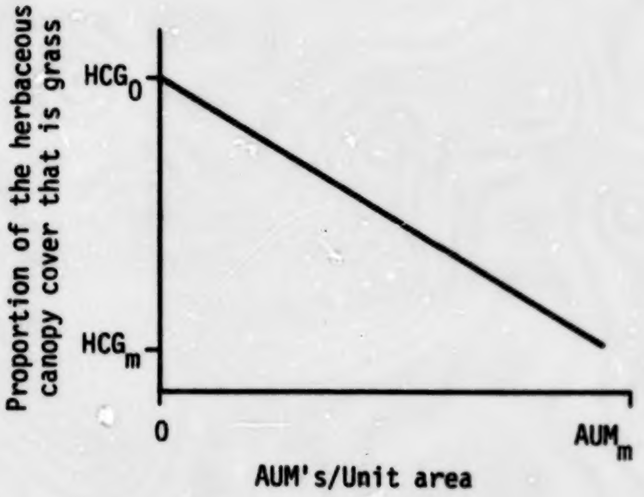
HCC_0 = the average percent herbaceous canopy cover in the complete absence of grazing

HCC_m = the average percent herbaceous canopy cover at the maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

Figure 5.4. Assumed relationship between grazing intensity and percent herbaceous canopy cover.

becomes more complex. The general approach can be exactly the same as described for percent herbaceous canopy cover, although the actual values used to define the relationship may be more difficult to estimate. Regardless of the difficulty in making the necessary estimates, the basic approach is to estimate the proportion of the herbaceous canopy cover that is grass under at least two conditions. The two easiest values to estimate are probably those resulting under no grazing conditions and maximum grazing conditions. These estimates can then be used to describe the general relationship between this variable and grazing intensity, as depicted in Figure 5.5, and expressed in Equation 5.10.



HCG_0 = the average proportion of the herbaceous canopy cover that is grass in the complete absence of grazing

HCG_m = the average proportion of the herbaceous canopy cover that is grass at maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

Figure 5.5. Assumed relationship between grazing intensity and the proportion of the herbaceous canopy cover that is grass.

$$HCG = \left[\frac{HCG_m - HCG_0}{AUM_m} \times AUM_i \right] + HCG_0 \qquad (5.10)$$

where HCG = the average proportion of the herbaceous canopy cover that is grass following a management action

HCG_0 = the average proportion of the herbaceous canopy cover that is grass in the complete absence of grazing

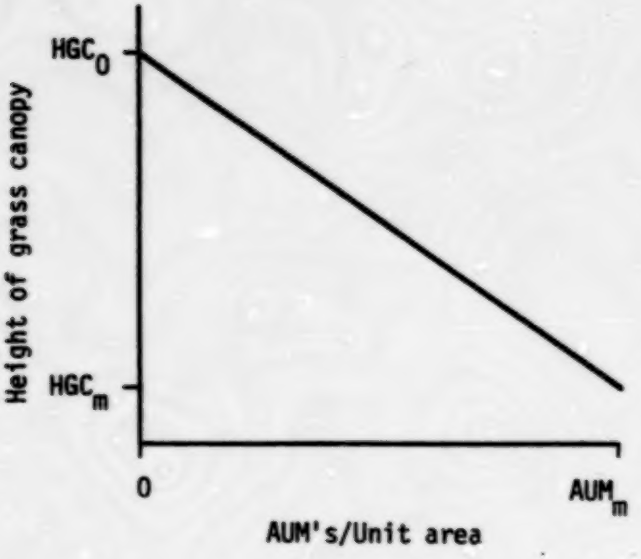
HCG_m = the average proportion of the herbaceous canopy cover that is grass at maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

AUM_i = the grazing intensity, measured in AUM's/unit area, to be implemented by management

Distance to a wetland >0.4 ha (DW). Because areas managed under different grazing systems (referring here to different grazing intensity) will provide habitat of different quality for wildlife, it is advisable to group grazed habitats by the similarity of the grazing system. Although the distance from the potential nesting habitat (i.e., the upland grazed cover types) to a wetland ≥0.4 ha will not vary with the grazing intensity, it is necessary to estimate the value of this variable in order to determine habitat suitability for the wildlife species identified in the Introduction. There are two ways to estimate this value. The first is to simply assume that the area managed with grazing is located, on the average, the same distance from a wetland ≥0.4 ha as was the cover type prior to implementing the grazing management action. In other cases, however, it will be obvious that the average conditions existing prior to implementing grazing management are not appropriate for the "new" (i.e., managed) cover types. In such cases, a map exercise using randomly selected points can be used to estimate the distance to a wetland ≥0.4 ha from a cover type managed under a given grazing system.

Maximum height of grass canopy (HGC). Depending on the timing of grazing, the maximum height of the grass canopy may be significantly influenced by grazing, or may not be influenced at all. For example, if grazing occurs after the peak of vegetative growth, this variable will not be affected. In such a situation, however, the impact on the visual obstruction of residual vegetation may be significant. As with previous variables describing vegetative structure, the maximum height of grass canopy is a function of grazing management only when the level of grazing intensity is being managed. Total exclusion of grazing will result in a change in the value of the maximum grass height, but such a change will be the same regardless of the amount of area being excluded from management. Management of grazing intensity, however, may have an influence on this variable. The approach that can be used to determine the relationship between grazing intensity and maximum grass height is the same as described previously for other vegetative structure variables. That is, estimates of the maximum grass height under the two extremes of grazing intensity, zero grazing and maximum sustainable intensity, can be used to define an inverse linear relationship between grass height and grazing intensity (Figure 5.6). Estimates of the dependent variable (grass height) can be made for any level of grazing intensity using Equation 5.11.



HGC_m = the maximum height of the grass canopy that is expected in the complete absence of grazing

HGC_m = the maximum height of the grass canopy that is expected at maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

Figure 5.6. Assumed relationship between grazing intensity and the maximum height of the grass canopy.

$$HGC = \left[\frac{HGC_m - HGC_0}{AUM_m} \times AUM_i \right] + HGC_0 \qquad (5.11)$$

where HGC = the maximum height of the grass canopy following a management action

HGC_0 = the maximum height of the grass canopy that is expected in the complete absence of grazing

HGC_m = the maximum height of the grass canopy that is expected at maximum sustainable grazing intensity

AUM_m = the maximum sustainable grazing intensity, measured in AUM's/unit area

AUM_i = the grazing intensity, measured in AUM's/unit area, to be implemented by management

Figure 5.6 and Equation 5.11 do not directly account for the very significant variable of timing of grazing. Users should develop the data for Figure 5.6 based on anticipated conditions, i.e., users must incorporate timing and duration of grazing when estimating the relationship between grazing intensity and grass height. For example, grazing that occurs in late summer and early fall may result in no relationship existing between grazing intensity and grass height, because the grass may have achieved its maximum height prior to grazing. Differences in level of grazing intensity will have no influence on grass height in such a situation.

Model Relationships

The presumed relationships between grazing control and a number of habitat variables were described in the preceding section. Table 5.3 presents a summary of the variables discussed in the model and a reference to the figure and equation where each relationship is described.

Application of the Model

This model can be used to evaluate the influence of grazing control on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. If the grazing management to be implemented consists simply of total exclusion of livestock, average annual values must be estimated by the user for the following variables: average visual obstruction measurement, percent herbaceous canopy cover, proportion of herbaceous canopy cover that is grass, and maximum height of grass canopy. If the intensity of grazing is to be the focus of the grazing control, the following information is necessary.

1. Baseline conditions for all variables.

2. Prediction of values for vegetative variables under conditions of no grazing and maximum grazing, or for two other levels of grazing intensity. This information is necessary for the average visual obstruction measurement, percent herbaceous canopy cover, proportion of the herbaceous canopy cover that is grass, and maximum height of grass canopy.

3. An estimate of the ratio between the area protected from grazing and the number of 4-ha grid cells classified as idle cover as a result.

13ɔ

Table 5.3. A summary of the habitat variables potentially affected by grazing control.

Habitat variable (acronym)	Equation(s)	Page(s)
Area of specified nonwetland cover type (ACT_j)	5.3, 5.4	5.7
Percent of area in pasture/hayland (PPH)	5.5	5.8
Percent of area in idle land (PIL)	5.6	5.8
Distribution of idle cover (DIC)	5.7	5.9
Average visual obstruction measurement (VO)	5.8	5.12
Percent herbaceous canopy cover (HCC)	5.9	5.13
Proportion of herbaceous canopy cover that is grass (HCG)	5.10	5.15
Distance to a wetland ≥0.4 ha (DW)	--	--
Maximum height of grass canopy (HGC)	5.11	5.16

It must be emphasized that grazing control may mean either total exclusion of livestock or management of the level of grazing. In the latter case, the management action may become quite complex because of the many factors that can be varied, particularly grazing intensity, timing, and duration. The relationships presented in this model assume that management either excludes livestock completely or varies only the intensity as measured by AUM's/unit area. No claim is made that this adequately covers all of the various combinations of grazing factors that can be implemented in the field. The relationships should be used simply as guidance for a means of evaluating the effects of grazing on habitat variables. Site-specific conditions obviously play a major role in determining the actual relationships and should be considered to the extent possible.

LITERATURE CITED

Bock, C.E., and B. Webb. 1984. Birds as grazing indicator species in southeastern Arizona. J. Wildl. Manage. 48(3):1045-1049.

Bock, C.E., J.H. Bock, W.R. Kenney, and V.M. Hawthorne. 1984. Responses of birds, rodents, and vegetation to livestock exclosure in a semidesert grassland site. J. Range Manage. 37(3):239-242.

Brown, R.L. 1961. Effects of land-use practices on sharp-tailed grouse. Job Comp. Rep. W-91-R-3 (Montana), Job No. II-F. 12 pp.

__________. 1966. Response of sharptail breeding populations to annual changes in residual grassland cover. Proc. Western Assoc. State Game and Fish Commissioners 46:219-222.

Bue, I.G., L. Blankenship, and W.H. Marshall. 1952. The relationship of grazing practices to waterfowl breeding populations and production on stock ponds in western South Dakota. Trans. N. Am. Wildl. Conf. 17:396-414.

Gray, J.R., C. Steiger, Jr., and J. M. Fowler. 1982. Characteristics of grazing systems. New Mexico State University, Agric. Exp. Station, Res. Rpt. 467. 16 pp.

Gjersing, F.M. 1975. Waterfowl production in relation to rest-rotation grazing. J. Range Manage. 28(1):37-42.

Hillman, C.N., and W.W. Jackson. 1973. The sharp-tailed grouse in South Dakota. South Dakota Dept. Game, Fish and Parks, Tech. Bull. 3. 62 pp.

Kaiser, P.H., S.S. Berlinger, and L.H. Fredrickson. 1979. Response of blue-winged teal to range management on waterfowl production areas in southeastern South Dakota. J. Range Manage. 32(4):295-298.

Kantrud, H.A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Can. Field-Nat. 95(4):404-417.

Kessler, W.B., and R.P. Bosch. 1982. Sharp-tailed grouse and range management practices in western grasslands. Proc. Wildl. Livestock Relationships Symp. 10:133-146.

Kirsch, L.M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33(4):821-828.

Kirsch, L.M., H.F. Duebbert, and A.D. Kruse. 1978. Grazing and haying effects on habitats of upland nesting birds. Trans. N. Am. Wildl. Nat. Res. Conf. 43:486-497.

Mattise, S.N., R.L. Linder, and G.D. Kobriger. 1982. Effects of grazing systems on sharp-tailed grouse habitats. Proc. Wildl. Livestock Relationships Symp. 10:124-132.

Rees, J.R. 1982. Potential use of cattle grazing to manage waterfowl nesting cover on Turnbull National Wildlife Refuge. Proc. Wildl. Livestock Relationships Symp. 10:86-93.

Ruyle, G.B., J.W. Menke, and D.L. Lancaster. 1980. Delayed grazing may improve upland waterfowl habitat. Calif. Agric. 34(11-12):29-31.

Sisson, L. 1976. The sharp-tailed grouse in Nebraska. Nebraska Game and Parks Comm., Lincoln. 88 pp.

6. WETLAND DEVELOPMENT

a. Construct seasonal wetlands
b. Construct semipermanent wetlands

MANAGEMENT ACTION INFORMATION

Purpose

Wetland construction is intended to create new seasonal (Class III) and semipermanent (Class IV) wetland habitat for species that use such wetlands, such as waterfowl and muskrats (wetland terminology follows the classification system of Stewart and Kantrud 1971). Depending on the surface cover type in which a wetland is constructed, there may be an associated loss in habitat quality or quantity for other wildlife species, such as the gray partridge, sharp-tailed grouse, and Baird's sparrow. A potential loss of nesting habitat for upland nesting waterfowl also exists.

Effects of Management Action

Construction of wetlands increases the overall area and number of wetlands available to wildlife. Wetland construction generally replaces a nonwetland cover type with a wetland cover type, although ephemeral and temporary wetlands may also be the host cover type for construction of seasonal or semipermanent wetlands. Habitat area of the host cover type (i.e., the cover type that is converted to a wetland) decreases as the result of wetland construction. Wetland construction may also influence the spatial relationship between upland habitat and wetland habitat. This may have a significant influence on waterfowl species that nest in uplands and use wetlands for pair bonding and brood rearing. Although wetland construction may be used to supplement an existing wetlands base or to mitigate for wetland losses, there is concern that "... it is probably impossible to replace natural habitat [with constructed wetlands] at the same value per unit area" (Rossiter and Crawford 1981:iii).

Maintenance and Management

Seasonal and semipermanent wetlands may be constructed in a number of sizes and shapes. Wetlands will be constructed only where topography is suitable for wetland construction, i.e., where ravines or natural catch basins exist. Construction of seasonal wetlands generally involves construction of low-head dikes, whereas earthen dams are required to construct semipermanent wetlands. The shape and extent of the resulting basins will conform to the topography of the catchment basins.

Constructed stockponds can take several forms. "Dugouts are steep-sided or rectangular excavations constructed to catch runoff or to intercept ground water" (Eng et al. 1979:6). Such stockponds are usually small, deep, and provide some waterfowl pair habitat, although their construction may reduce overall habitat when they are constructed in natural wetland basins. Pit-retention reservoirs include a dam and dugout combination (Eng et al. 1979). Pit-rentention reservoirs are generally shallow, and provide waterfowl brood habitat only in years of abundant water. "Retention reservoirs are constructed by building dams across natural waterways" (Eng et al. 1979:9). Waterfowl pair and brood use is higher on retention reservoirs than on dugouts or pit-retention reservoirs (Lokemoen 1973). Eng et al. (1979) provides guidance on stockpond construction for waterfowl use, including desirable design criteria.

Eng et al. (1979) concluded that waterfowl use of constructed wetlands increases with pond age, in response to increased vegetation development and pond fertility. Rossiter and Crawford (1981) found that constructed wetlands provided less suitable waterfowl habitat due to lower densities of macroinvertebrates and lower plant species diversity. However, the constructed wetlands in their study were all <5 years old. A drawdown cycle of 5-7 years was recommended to maintain high invertebrate productivity and an approximately 1:1 ratio of emergent vegetation to open water, considered the most attractive waterfowl habitat (Bishop et al. 1979). Baldassare and Nauman (1981) also recommended periodic drying and flooding of emergent vegetation to increase invertebrate productivity on constructed wetlands in Wisconsin. Wetlands in which water level manipulation is desired will require water-level control structures.

Labor and Materials

Cost information presented in this section is necessarily based on wetlands of fixed size. Costs will obviously vary with construction site and the availability of equipment and materials. A constructed seasonal wetland on the Garrison Diversion Unit study was considered to be 0.4 ha in extent, and included construction of an earthen dike 0.6 m high, with an average top width of 1.2 m and average length of 22.9 m. Average depth was considered to be 15.2 cm, although this will be determined by the shape of the catchment basin. A constructed semipermanent wetland was considered to be 2.0 ha in extent, and included an earthen dam 1.5 m high, with an average top width of 2.4 m, an average bottom width of 7.6 m, and an average length of 22.9 m. The average constructed semipermanent wetland was assumed to have an average depth of 0.9 m.

Estimated costs for constructing seasonal and semipermanent wetlands from the Garrison Diversion Unit study are summarized in Table 6.1. The cost estimates include design, construction of the dike or dam, earth moving, and planting dense nesting cover during construction. An annual maintenance cost of $40 per seasonal wetland and $100 per semipermanent wetland is included in Table 6.1. These costs were determined as 2% of the initial contruction costs. The constant cost of maintenance from year to year is based on an assumption of zero inflation throughout the period.

Table 6.1. Assumed design parameters and estimated costs for construction of a seasonal wetland or a semipermanent wetland in North Dakota.[a]

	Wetland Class	
	Seasonal (III)	Semipermanent (IV)
Average size	0.4 ha (1.0 acre)	2.0 ha (5.0 acres)
Average depth	15 cm (6 inches)	0.9 m (3 ft)
Height of earthen dam	0.6 m (2 ft)	1.5 m (5 ft)
Top width of dam	1.2 m (4 ft)	2.4 m (8 ft)
Bottom width of dam	---	7.6 m (25 ft)
Average length of dam	22.9 m (75 ft)	22.9 m (75 ft)
Construction costs	$2,000.00	$5,000.00
Annual maintenance (2% of construction costs)	40.00	100.00

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

Lokemoen (1984) estimated costs for construction of impoundments and level ditch ponds. These costs are summarized in Table 6.2; no maintenance costs were provided for level ditch ponds. Impoundments were assumed to have a 50-year life, whereas level ditches were assumed to have a 20-year life. The small impoundments discussed by Lokemoen (1984) were constructed by damming small intermittent streams. Level ditch ponds were constructed by excavating in areas with high water tables. Although not classified according to the wetland classification system of Stewart and Kantrud (1973), the constructed wetlands discussed by Lokemoen (1984) would probably be considered as semipermanent or permanent wetlands. Construction of impoundments or level ditch ponds were expensive activities because of the need for heavy earth-moving equipment.

Table 6.2. Cost categories and estimated costs for constructing small impoundments and level ditch ponds in the Dakota pothole region (from Lokemoen 1984).

Establishment and maintenance	Cost
SMALL IMPOUNDMENTS	
Establishment (per acre)	
Earth moving (1,300 yd^3)	$1,950.00
Surveying	50.00
Seeding	100.00
Total establishment cost	$2,100.00
Maintenance (per acre)	
Earth moving	975.00
Surveying	25.00
Seeding	50.00
Total annual maintenance cost	$1,050.00
LEVEL DITCH PONDS	
Establishment (per acre)	
Earth moving (6,453 yd^3)	6,453.00
Surveying	50.00
Total establishment cost	$6,503.00

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Wetland construction can occur in a number of cover types depending on the suitability of topography. The potential host cover types for wetland construction include tame grassland, native grassland, cropland, shrubland, woodland, ephemeral wetlands, and temporary wetlands. Although several host cover types may be suitable for wetland construction, users should identify specific study constraints regarding actual host cover types for a given application. For example, users may not wish to convert existing ephemeral and temporary wetlands to seasonal or semipermanent wetlands.

Minimum management area. Cost information presented previously for wetland construction was based on an average size of 0.4 ha for seasonal wetlands and 2.0 ha for semipermanent wetlands. However, actual wetland size will be site specific and a function of topography. Minimum management area is the minimum size wetland that will maintain water levels to support shallow-marsh vegetation (as defined by Stewart and Kantrud 1971) for a seasonal wetland, and deep-marsh vegetation for a semipermanent wetland. These minimum areas are assumed to be 0.04 ha for a seasonal wetland, and 0.8 ha for a semipermanent wetland.

Model Description

Overview. Construction of seasonal and semipermanent wetlands influences a number of habitat variables (Table 6.3). The direction of change indicated in Table 6.2 refers to the value of the habitat variable. The resultant change in the suitability of a given variable for any given species depends on the structure of the individual HSI model, and is not necessarily the same as the direction of change indicated in Table 6.3. For example, construction of wetlands will decrease the distance from upland habitat, which may increase the nesting suitability of the habitat for upland nesting waterfowl.

Wetland construction may cause an increase or decrease in the value of a specific variable, depending on the circumstances of construction. For example, if a seasonal wetland is constructed in a basin currently supporting a temporary wetland, the area and number of temporary wetlands will decrease while the area and number of seasonal wetlands will increase.

Structural habitat variables within constructed wetlands will change over time, but not in response to the number or area of wetlands constructed. Average annual values for such variables must be estimated in order to determine Average Annual Habitat Units for a given species. This can be done by estimating values for each variable at selected target years over the life of the management action. Lokemoen (1984) assigned a life expectancy of 50 years to constructed impoundments, based on a maximum planning period. In order to determine impacts of wetland construction on the six wildlife species identified in the Introduction, average annual values must be estimated for the following variables over the assumed life of the wetland: (1) percent canopy cover of emergent herbaceous vegetation, and (2) percent of emergent herbaceous vegetation consisting of cattail.

The variables that are influenced by construction of seasonal or semipermanent wetlands are discussed individually below.

Table 6.3. Habitat variables potentially affected by construction of wetlands.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Number of wetlands of a specified wetland class (NW_i)	X	X
Area of wetlands of a specified wetland class (AW_i)	X	X
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	X	X
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	X	X
Area of specified nonwetland cover type (ACT_j)		X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)	X	X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)	X	X
Distribution of idle cover (DIC)	X	X
Distance to a wetland ≥0.4 ha (DW)		X

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of wetland construction. Variables for which both a positive and negative change are indicated are generally the result of changes in different cover types.

Number of wetlands of a specified wetland class (NW_i). Construction of seasonal wetlands will increment the number of Class III wetlands by the number of such wetlands constructed. Construction of semipermanent wetlands will increment the number of Class IV wetlands by the number of such wetlands constructed. If wetland construction occurs in ephemeral or temporary wetlands, then the number of Class I or II wetlands will decrease by the number of these wetlands that are changed to Class III or Class IV due to construction. These relationships are expressed in Equation 6.1:

$$NW_i = NW_{iB} \pm NW_{iC} \qquad (6.1)$$

where NW_i = the number of wetlands of class i present following a management action

NW_{iB} = the number of wetlands of class i prior to management

NW_{iC} = the number of constructed wetlands of class i when i equals Class III (seasonal) or Class IV (semipermanent); or, the number of wetland basins of class i converted to wetlands of another class by wetland construction [i.e., when i equals Class I (ephemeral) or Class II (temporary)]

Area of wetlands of a specified wetland class (AW_i). Construction of seasonal or semipermanent wetlands will influence this variable as it influences number of wetlands of a specified wetland class. The area of seasonal or semipermanent wetlands will increase by the total area of constructed seasonal or semipermanent wetlands, respectively. The area of ephemeral or temporary wetlands may decrease if wetland construction occurs in these cover types. These relationships are expressed in Equation 6.2:

$$AW_i = AW_{iB} \pm AW_{iC} \qquad (6.2)$$

where AW_i = the area of wetlands of class i present following a management action

AW_{iB} = the area of wetlands of class i prior to management

AW_{iC} = the area of constructed wetlands of class i when i equals Class III (seasonal) or Class IV (semipermanent); or, the area of class i wetlands converted to another Wetland Class by wetland construction [i.e., when i equals Class I (ephemeral) or Class II (temporary)]

Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i). The influence of wetland construction on this variable is functionally identical to the influence on the number of wetlands of a specified wetland class, described previously (Equation 6.1). The only difference is that this variable considers only those wetlands ≥0.4 ha. The relationship between wetland construction and this variable is expressed in Equation 6.3:

$$NWL_i = NWL_{iB} \pm NWL_{iC} \tag{6.3}$$

where NWL_i = the number of wetlands ≥0.4 ha of class i present following a management action

NWL_{iB} = the number of wetlands ≥0.4 ha of class i prior to management

NWL_{iC} = the number of constructed wetlands ≥0.4 ha of class i when i equals Class III (seasonal) or Class IV (semipermanent); or the number of wetland basins ≥0.4 ha of class i converted to wetlands of another class by wetland construction [i.e., when i equals Class I (ephemeral) or Class II (temporary)]

Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i). The influence of wetland construction on this variable is functionally identical to the influence on the area of wetlands of a specified wetland class, described previously (Equation 6.2). The only difference is that this variable considers only those wetlands ≥0.4 ha. The relationship between wetland construction and this variable is expressed in Equation 6.4:

$$AWL_i = AWL_{iB} \pm AWL_{iC} \tag{6.4}$$

where AWL_i = the area of wetlands ≥0.4 ha of class i present following a management action

AWL_{iB} = the area of wetlands ≥0.4 ha of class i prior to management

AWL_{iC} = the area of constructed wetlands ≥0.4 ha of class i when i equals Class III (seasonal) or Class IV (semipermanent); or, the area of wetlands ≥0.4 ha of class i converted to wetlands of another class by wetland construction [i.e., when i equals Class I (ephemeral) or Class II (temporary)]

Area of specified nonwetland cover type (ACT_j). Wetland construction involves the change of one surface cover type to another. The upland cover type in which a wetland is constructed is referred to as the host cover type. Wetland construction causes a decrease in the area of the host cover type, as expressed in Equation 6.5:

$$ACT_j = ACT_{jB} - AW_j \tag{6.5}$$

where ACT_j = the area of host cover type j following a management action

ACT_{jB} = the area of host cover type j prior to management

AW_j = the total area of all wetlands constructed in host cover type j

Percent of area in cropland (PC). Wetlands may be constructed in existing croplands as well as in other cover types. The effect of wetland construction in croplands is to reduce the overall proportion of the study area accounted for by cropland cover types. This relationship is expressed in Equation 6.6:

$$PC = \left[\frac{ACT_3 - AW_3}{\text{Total study area}}\right] \times 100 \tag{6.6}$$

where PC = the percent of an area in cropland following a management action

ACT_3 = the area of cropland (nonwetland cover type 3) prior to management

AW_3 = the total area of all wetlands constructed in cropland (nonwetland cover type 3)

Percent of cropland cover type in corn or other grain crops (PCG). Wetland construction in cropland that currently produces corn or grains will reduce the relative amount of the cropland area in these crops. Alternatively, wetland construction in crops other than corn or other grains will increase the relative proportion of the cropland area in these types of crops. These relationships are expressed in Equation 6.7:

$$PCG = \left[\frac{ACG_B - AWCG}{ACT_{3B} - AW_3}\right] \times 100 \tag{6.7}$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn and other grain crops prior to management

AWCG = the area of wetlands constructed in cropland producing corn and other grain crops

ACT_{3B} = the total area of cropland (nonwetland cover type 3) prior to management

AW_3 = the total area of all wetlands constructed in cropland (nonwetland cover type 3), regardless of the crop being grown

Percent of area in pasture/hayland (PPH). This variable is an estimate of the proportion of an area supporting the land uses of grazing or mowing. Pasture/hayland is not included as a distinct cover type. Rather, pasture/hayland results from certain land use on tame or native grasslands. Functionally, the relationship between this variable and wetland construction is similar to the percent of area in cropland, discussed previously (Equation 6.6). The relationship is expressed in Equation 6.8:

$$PPH = \left[\frac{APH_B - AWPH}{\text{Total study area}}\right] \times 100 \qquad (6.8)$$

where PPH = percent of an area in pasture/hayland land uses following a management action

APH_B = the area of pasture/hayland prior to management

AWPH = the total area of all wetlands constructed in cover types used as pasture or hayland

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types, including tame grassland, native grassland, shrubland, or woodland. Wetlands constructed in habitats that are currently grazed, hayed, or in cropland will not influence this variable. However, wetland construction in cover types that are currently idle will lower the percent of an area in idle land. This relationship is expressed in Equation 6.9:

$$PIL = \left[\frac{AIL_B - AWIL}{\text{Total study area}}\right] \times 100 \qquad (6.9)$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

AWIL = the total area of all wetlands constructed in cover types that are not grazed, hayed, or in crop production

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km² sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed and do not support crops. Wetland construction in idle habitat may reduce this variable, but only if all the idle habitat in a given 4-ha block is eliminated. The most accurate method of measuring the impact of wetland construction on this variable is to simply estimate the variable using a grid overlay on an area map prior to and following wetland construction. The functional relationship is a simple subtraction, as shown in Equation 6.10:

$$DIC = NGIL_B - NGWC \tag{6.10}$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

$NGIL_B$ = the number of 4-ha grid cells per 2.59 km² that contain or border idle cover prior to management

NGWC = the number of grid cells in which idle cover is eliminated as a result of wetland construction

Use of a grid overlay before and after wetland construction to estimate the action's impact on distribution of idle cover may be impractical in some situations. It may be reasonable to assume in such cases that wetland construction will not affect the distribution of idle cover. This is particularly appropriate when the following assumptions hold true. First, wetland construction will not generally occur in idle habitat, since such habitat provides nesting cover for upland nesting species such as many waterfowl and sharp-tailed grouse. Second, when wetland construction eliminates idle cover, it may not eliminate all idle cover in a 4-ha square. Under these conditions, there will be no change in the distribution of idle cover due to wetland construction.

Distance to a wetland ≥0.4 ha (DW). Construction of seasonal and semipermanent wetlands ≥0.4 ha will potentially change the distance from nonwetland cover types to a wetland ≥0.4 ha. The most accurate way of determining the distance is through a map exercise; i.e., potential sites for construction of wetlands ≥0.4 ha are plotted on study area maps and distances recalculated using the same procedure used to estimate distances prior to wetland construction. This process can be repeated for any set and sequence of wetland construction, e.g., to evaluate the impacts of a proposed construction schedule. This approach may not be practical in a given application of this model. An alternative to this approach is to conduct a map exercise using all wetlands ≥0.4 ha that can potentially be constructed and recalculate distances for only the maximum wetland construction scenario. This approach will provide a model user with baseline distances from each nonwetland type and the shortest distances that can be expected under specified study constraints. The functional relationship between these two points can take a number of forms, including a linear relationship (Figure 6.1a) and a negative exponential relationship (Figure 6.1b).

The linear function assumes an equal proportional decrease in distance for a given proportion of the maximum number of wetlands that are actually constructed. For example, if 25% of the maximum wetlands are built, the distance from a given cover type following wetland construction is 25% less than it was prior to the wetland construction, regardless of the actual distribution of the constructed wetlands. The negative exponential function describes a relationship based on assumed equal distribution of constructed wetlands. Regardless of the function used, distances from each nesting cover type to a wetland ≥0.4 ha must be estimated for two points, the first representing conditions without wetland construction (DW_{jB} in Figure 6.1), and the second under the condition of maximum wetland construction (DW_{jC} in Figure 6.1).

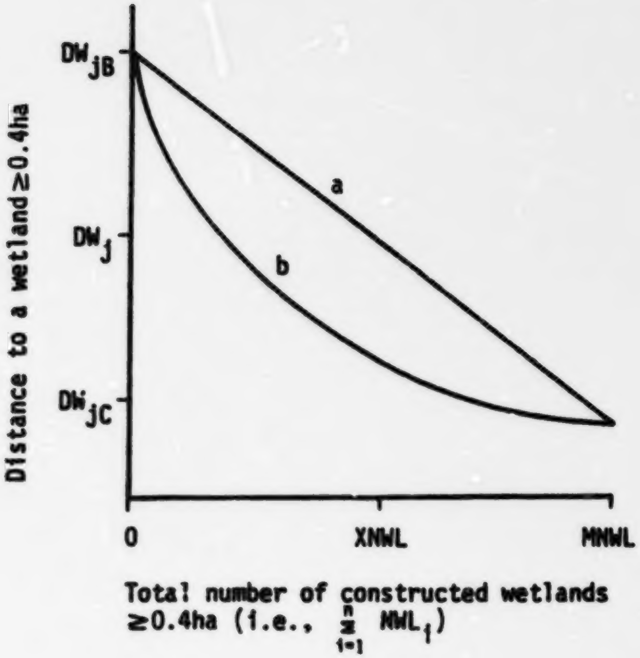
Model Relationships

The presumed relationships between wetland construction and a number of habitat variables were described in the preceding section. Table 6.4 presents a summary of the variables discussed in this model and a reference to the equation or figure where the relationship is presented.

Application of the Model

This model can be used to evaluate the influence of constructing seasonal or semipermanent wetlands on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the model user must supply site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all habitat variables.
2. The maximum number and area of seasonal wetlands that can be constructed in each cover type.
3. The maximum number and area of semipermanent wetlands that can be constructed in each cover type.
4. An estimate of the distance from each nonwetland habitat type (except woodland) to a wetland ≥0.4 ha under the condition of construction of all possible wetlands ≥0.4 ha.



If a, then:

$$DW_j = [((DW_{jC} - DW_{jB})/MNWL) \times XNWL] + DW_{jB}$$

If b, then:

$$DW_j = ae^{bx}$$

where DW_{jB} = distance from cover type j to a wetland ≥0.4 ha under baseline conditions

DW_{jC} = distance from cover type j to a wetland ≥0.4 ha under conditions of maximum wetland construction

MNWL = the maximum number of constructed wetlands ≥0.4 ha

XNWL = the number of wetlands to be constructed

a = DW_{jB} (see above)

$x = \sum_{i=1}^{n} NWL_i$, where NWL_i = the number of wetlands of class i to be constructed, and n = the number of wetland classes to be constructed

$b = (\ln(DW_{jC}) - \ln(DW_{jB}))/MNWL$

Figure 6.1. Two potential functions defining the relationship between baseline and maximum estimates of distance from a given cover type providing waterfowl nesting habitat to a wetland ≥0.4 ha.

Table 6.4. A summary of the habitat variables potentially affected by construction of seasonal or semipermanent wetlands.

Variable (acronym)	Equation	Figure	Page(s)
Number of wetlands of a specified wetland class (NW_i)	6.1	-	6.7
Area of wetlands of a specified wetland class (AW_i)	6.2	-	6.7
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	6.3	-	6.8
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	6.4	-	6.9
Area of specified nonwetland cover type (ACT_j)	6.5	-	6.9
Percent of area in cropland (PC)	6.6	-	6.10
Percent of cropland cover type in corn or other grain crops (PCG)	6.7	-	6.10
Percent of the area in pasture/hayland (PPH)	6.8	-	6.11
Percent of the area in idle land (PIL)	6.9	-	6.11
Distribution of idle cover (DIC)	6.10	-	6.12
Distance to a wetland ≥0.4 ha (DW)	-	6.1	6.14

LITERATURE CITED

Baldassare, G.A., and L.E. Nauman. 1981. Factors affecting waterfowl use and production in man-made flowages in central Wisconsin. Wisc. Acad. Arts and Letters 69:4-14.

Bishop, R.A., R.D. Andrews, and R.J. Bridges. 1979. Marsh management and its relationship to vegetation, waterfowl, and muskrats. Proc. Iowa Acad. Sci. 86(2):50-56.

Eng, R.L., J.D. Jones, and F.M. Gjersing. 1979. Construction and management of stockponds for waterfowl. U.S. Bur. Land Manage. Tech. Note 327. 39 pp.

Lokemoen, J.T. 1973. Waterfowl production on stock-watering ponds in the northern plains. J. Range Manage. 26(3):179-184.

____________. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

Rossiter, J.A., and R.D. Crawford. 1981. Evaluation of constructed ponds as a means of replacing natural wetland habitat affected by highway projects in North Dakota. Final Rep. FHWA-ND-RD-(2)-79A, prep. for U.S. Dept. Trans., Fed. Highway Admin., Office of Development, Washington, DC. 171 pp.

Stewart, R.E., and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Bur. Sport Fish. Wildl. Resour. Publ. 92. 57 pp.

c. Restore drained wetlands

MANAGEMENT ACTION INFORMATION

Purpose

The purpose of restoring drained wetlands is to increase the quality of habitat available to wetland-dependent wildlife species. Drained wetlands may occur in any nonwetland surface cover type, although most drained wetlands will likely be in croplands. Since restoration of drained wetlands involves a change of one surface cover type to another, this management action may result in loss of habitat for species inhabiting the surface cover type present prior to wetland restoration.

Effects of Management Action

The effects of restoring drained wetlands are similar to those of constructing seasonal or semipermanent wetlands except that restoration may apply to any of the wetland classes defined by Stewart and Kantrud (1971). In practice, however, most drained wetlands will have been drained for crop production and will generally be the smaller, most easily drained wetlands. For example, wetlands with tilled bottom soils accounted for 29% of the wetland area and 52% of the number of wetlands in a North Dakota study (Stewart and Kantrud 1973). The tilled wetlands were all classed as either temporary (Class II) or seasonal (Class III) wetlands.

Wetland restoration may also influence the spatial relationship between upland habitat and wetland habitat. This may have a significant influence on waterfowl species that nest in uplands and use wetlands for pair bonding and brood rearing. The area of the cover types in which wetlands are restored will decrease as a result of this management action. The impact of this reduction on wildlife will depend on the species of interest as well as the cover type involved. For example, restoration of wetlands in cropland may have little influence on nesting suitability for waterfowl, since croplands provide poor quality nesting habitat for waterfowl (Higgins 1977). However, the impact of wetland restoration in croplands on species that use croplands extensively (e.g., the gray partridge) may be more significant.

Maintenance and Management

The process of draining wetlands consists of digging a ditch from the wetland, thus allowing the wetland to dry. After the soils have dried, the wetlands are generally planted with crops or grasses and used for agricultural purposes. Drainage is generally restricted to temporary (Class II) and seasonal (Class III) wetlands (see Stewart and Kantrud 1973), although semipermanent (Class IV) and permanent (Class V) wetlands may also be drained. Alkali (Class VI) wetlands are generally not drained because the alkaline soils are generally unsuitable for agricultural purposes. Ephemeral (Class I) wetlands retain water for only a short period in the spring. Such wetlands are not generally a hindrance to agricultural use and so are not often drained. Wetland restoration can occur wherever drainage has occurred, and will most likely be in cropland, native grassland, and tame grassland. Restoration is accomplished by plugging or filling the ditch so that water can be impounded to recreate a wetland habitat.

Labor and Materials

Construction requirements for restoring wetlands are minor, in many instances requiring only hand labor. A backhoe or small bulldozer may be required to plug larger ditches. The time and labor to plug a drainage ditch in a temporary or seasonal wetland is estimated to be 3 hours, including travel time. The time required to plug a drainage ditch in a semipermanent or permanent wetland is estimated to be 5 hours, including travel time. Initial costs for wetland restoration are summarized in Table 6.5. The costs in Table 6.5 do not include the costs of water control structures, the costs of periodic drawdowns, or any annual maintenance costs. If these features are to be included in restored wetlands, the costs presented for wetland construction (Table 6.1) will provide a better approximation of actual costs than those presented in Table 6.5. Although the total initial costs are the same for restoration of temporary and seasonal wetlands, and for semipermanent and permanent wetlands, the cost per unit area of restored wetland will very likely differ, depending on the size of the wetlands restored. This will be determined by past drainage activity and by topography.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Wetland restoration can occur in any surface cover type depending on past drainage activities. The potential host cover types for wetland construction include cropland, tame grassland, and native grassland. The purpose of wetland drainage is to make available more land surface for agricultural activities such as crop production, livestock grazing, and hay production. Therefore, habitats such as woodland and shrubland will not generally be considered with this model. Actual wetland restoration will most likely be limited to temporary, seasonal, semipermanent, and permanent wetlands, because these wetland classes are the ones typically drained for

157

Table 6.5. Estimated costs for restoration of wetlands by wetland class in North Dakota.[a]

Wetland class[b]	Average cost/wetland
Temporary (II)	$150
Seasonal (III)	$150
Semipermanent (II)	$250
Permanent (V)	$250

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

[b] Ephemeral (I) and Alkali (VI) wetlands are not included since wetlands of these classes are generally not drained and are, therefore, unavailable for restoration.

agricultural purposes. Ephemeral wetlands do not generally contain water long enough to interfere with agricultural activities and are not usually drained. Alkali wetlands are not often drained for agricultural purposes due to the alkaline conditions of the bottom soils.

Minimum management area. The minimum size restorable wetland is a site-specific parameter that depends upon past drainage activity and topography. Therefore, no minimum management area is specified in this model.

Model Description

Overview. Restoration of wetlands influences the same habitat variables as does wetland construction (Table 6.3, p. 6.6). As noted in the wetland construction management action model, the direction of change indicated in Table 6.3 refers to the value of the habitat variable. The resultant change in the suitability of a given variable for any given species depends on the structure of the individual HSI model, and is not necessarily the same as the direction of change indicated in Table 6.3. For example, construction of wetlands will decrease the distance from upland habitat, which may increase the nesting suitability of the habitat for upland nesting waterfowl.

Wetland restoration may cause an increase or decrease in the value of a specific variable, depending on the circumstances of restoration. For example, if a seasonal wetland is restored in a basin currently supporting cropland, the area of cropland will decrease while the area and number of seasonal wetlands will increase.

Structural habitat variables within restored wetlands will change over time, but not in response to the number or area of restored wetlands. Average annual values for such variables must be estimated in order to determine Average Annual Habitat Units for a given species. This can be done by estimating values for each variable at selected target years over the life of the management action. In order to determine impacts of wetland restoration on the six wildlife species identified in the Introduction, average annual values must be estimated for the following variables over the assumed life of the wetland: (1) percent canopy cover of emergent herbaceous vegetation, and (2) percent of emergent herbaceous vegetation consisting of cattail.

The influence of wetland restoration on most habitat variables is functionally identical to the influence of wetland construction, except that wetland restoration applies to more wetland classes than does wetland construction. The variables that are influenced by wetland restoration are discussed individually below. Much of the following discussion is only slightly modified from the discussion in the wetland construction management action model.

Number of wetlands of a specified wetland class (NW_i). Restoration of wetlands of a given class will increment the number of wetlands in that class by the number of such wetlands restored. The relationship is expressed in Equation 6.11:

$$NW_i = NW_{iB} + NW_{iR} \qquad (6.11)$$

where NW_i = the number of wetlands of class i present following a management action

NW_{iB} = the number of wetlands of class i prior to management

NW_{iR} = the number of restored wetlands of class i

Area of wetlands of a specified wetland class (AW_i). Restoration of wetlands will influence this variable as it influences number of wetlands of a specified wetland class. The area of wetlands of a given class will increase by the total area of restored wetlands of that class. The relationship is expressed in Equation 6.12:

$$AW_i = AW_{iB} + AW_{iR} \tag{6.12}$$

where AW_i = the area of wetlands of class i present following a management action

AW_{iB} = the area of wetlands of class i prior to management

AW_{iR} = the area of restored wetlands of class i

Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i). The influence of wetland restoration on this variable is functionally identical to the influence on the number of wetlands of a specified wetland class, described previously (Equation 6.11). The only difference is that this variable considers only those wetlands ≥0.4 ha. The relationship between wetland restoration and this variable is expressed in Equation 6.13:

$$NWL_i = NWL_{iB} + NWL_{iR} \tag{6.13}$$

where NWL_i = the number of wetlands ≥0.4 ha of class i present following a management action

NWL_{iB} = the number of wetlands ≥0.4 ha of class i prior to management

NWL_{iR} = the number of restored wetlands ≥0.4 ha of class i

Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i). The influence of wetland restoration on this variable is functionally identical to the influence on the area of wetlands of a specified wetland class, described previously (Equation 6.12). The only difference is that this variable considers only those wetlands ≥0.4 ha. The relationship between wetland restoration and this variable is expressed in Equation 6.14:

$$AWL_i = AWL_{iB} + AWL_{iR} \tag{6.14}$$

where AWL_i = the area of wetlands ≥0.4 ha of class i present following a management action

AWL_{iB} = the area of wetlands ≥0.4 ha of class i prior to management

AWL_{iR} = the area of restored wetlands ≥0.4 ha of class i

Area of specified nonwetland cover type (ACT_j). Wetland restoration involves the change of one surface cover type to another. The upland cover type in which a wetland is constructed is referred to as the host cover type. Wetland restoration causes a decrease in the area of the host cover type, as expressed in Equation 6.15:

$$ACT_j = ACT_{jB} - ARW_j \tag{6.15}$$

where ACT_j = the area of host cover type j following a management action

ACT_{jB} = the area of host cover type j prior to management

ARW_j = the total area of all wetlands restored in host cover type j

Percent of area in cropland (PC). Most wetland restoration will probably occur in cropland cover types, because wetlands are generally drained to increase land available for crop production. The effect of wetland restoration in croplands is to reduce the overall proportion of the study area accounted for by cropland cover types. This relationship is expressed in Equation 6.16:

$$PC = \left[\frac{ACT_{3B} - ARW_3}{\text{Total study area}} \right] \times 100 \qquad (6.16)$$

where PC = the percent of an area in cropland following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

ARW_3 = the total area of all wetlands restored in cropland (nonwetland cover type 3)

Percent of cropland cover type in corn or other grain crops (PCG). Wetland restoration in cropland that currently produces corn or grains will reduce the relative amount of the cropland area in these crops. Alternatively, wetland restoration in crops other than corn or other grains will increase the relative proportion of the cropland area in these types of crops. These relationships are expressed in Equation 6.17:

$$PCG = \left[\frac{ACG_B - ARWCG}{ACT_{3B} - ARW_3} \right] \times 100 \qquad (6.17)$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn and other grain crops prior to management

$ARWCG$ = the area of wetlands restored in cropland producing corn and other grain crops

ACT_{3B} = the total area of cropland (nonwetland cover type 3) prior to management

ARW_3 = the total area of all wetlands restored in cropland (non-wetland cover type 3), regardless of the crop being grown

Percent of area in pasture/hayland (PPH). This variable is an estimate of the proportion of an area supporting the land uses of grazing or mowing. Pasture/hayland is not included as a distinct cover type. Rather, pasture/hayland results from certain land use on tame or native grasslands. Functionally, the relationship between this variable and wetland restoration is similar to the percent of area in cropland, discussed previously (Equation 6.16). The relationships are expressed in Equation 6.18:

$$PPH = \left[\frac{APH_B - ARWPH}{\text{Total study area}}\right] \times 100 \qquad (6.18)$$

where PPH = percent of an area in pasture/hayland land uses following a management action

APH_B = the area of pasture/hayland prior to management

$ARWPH$ = the total area of all wetlands restored in cover types used as pasture or hayland

Percent of area in idle land (PIL). Idle land is any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types, including tame grassland, native grassland, shrubland, or woodland. Wetlands restored in habitats that are not grazed, hayed, or in cropland will not influence this variable. However, wetland restoration in cover types that are currently idle will lower the percent of an area in idle land. This relationship is expressed in Equation 6.19:

$$PIL = \left[\frac{AIL_B - ARWIL}{\text{Total study area}}\right] \times 100 \qquad (6.19)$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

ARWIL = the total area of all wetlands restored in habitats that are not grazed, hayed, or in crop production

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km² sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed and do not support crops. Wetland restoration in idle habitat may reduce this variable, but only if all the idle habitat in a given 4-ha block is eliminated. The most accurate method of measuring the impact of wetland restoration on this variable is to simply estimate the variable using a grid overlay on an area map prior to and following wetland restoration. The functional relationship is a simple subtraction, as shown in Equation 6.20:

$$DIC = NGIL_B - NGWR \tag{6.20}$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

$NGIL_B$ = the number of 4-ha grid cells per 2.59 km² that contain or border idle cover prior to management

NGWR = the number of grid cells per 2.59 km² in which idle cover is eliminated as a result of wetland restoration

Use of a grid overlay before and after wetland restoration to estimate the action's impact on distribution of idle cover may be impractical in some situations. It may be reasonable to assume in such cases that wetland restoration will not affect the distribution of idle cover. This is particularly appropriate when the following assumptions hold true. First, wetland restoration will generally occur in habitats that currently produce crops, are mowed, or are grazed, i.e., in habitats that do not meet the definition of idle. Second, when wetland restoration does eliminate idle cover, it may not eliminate all idle cover in a 4-ha square. Under these conditions, there will be no change in the distribution of idle cover due to wetland restoration.

Distance to a wetland ≥0.4 ha (DW). Restoration of wetlands ≥0.4 ha will potentially change the distance from nonwetland cover types to a wetland ≥0.4 ha. The most accurate way of determining the distance is through a map exercise; i.e., potential sites for restoration of wetlands ≥0.4 ha are plotted on study area maps and distances recalculated using the same procedure used to estimate distances prior to wetland restoration. This process can be repeated for any set and sequence of wetland restoration, e.g., to evaluate the impacts of a proposed restoration schedule. This approach may not be practical in a given application of this model. An alternative to this approach is to conduct a map exercise using all wetlands ≥0.4 ha that can potentially be restored and recalculate distances for only the maximum wetland restoration scenario. This approach will provide a model user with baseline distances from each nonwetland type and the shortest distances that can be expected under specified study constraints. The functional relationship between these two points can take a number of forms, including a linear relationship (Figure 6.1a, p. 6.14) and a negative exponential relationship (Figure 6.1b, p. 6.14).

The linear function assumes an equal proportional decrease in distance for a given proportion of the maximum number of wetlands that are actually restored. For example, if 25% of the maximum restorable wetlands are actually restored, the distance from a given cover type following restoration is 25% less than it was prior to restoration, regardless of the actual distribution of the restored wetlands. The negative exponential function describes a relationship based on assumed equal distribution of restored wetlands. Regardless of the function used, distances from each nesting cover type to a wetland ≥ 0.4 ha must be estimated for two points, the first representing conditions without wetland restoration (DW_{jB} in Figure 6.1), and the second under the condition of maximum wetland restoration (DW_{jC} in Figure 6.1).

Model Relationships

The presumed relationships between wetland restoration and a number of habitat variables were described in the preceding section. Table 6.6 presents a summary of the variables discussed in this model and a reference to the equation(s) or figure where each relationship is presented.

Application of the Model

This model can be used to evaluate the influence of restoring wetlands on selected habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the model user must supply site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all habitat variables.
2. The minimum number and area of each class of wetlands that can be restored in each cover type.
3. An estimate of the distance from each nonwetland habitat type (except woodland) to a wetland ≥0.4 ha under the conditions of restoration of all possible wetlands ≥0.4 ha.

Table 6.6. A summary of the habitat variables potentially affected by wetland restoration.

Variable (acronym)	Equation	Figure	Page(s)
Number of wetlands of a specified wetland class (NW_i)	6.11	-	6.20
Area of wetlands of a specified wetland class (AW_i)	6.12	-	6.21
Number of wetlands ≥0.4 ha of a specified wetland class (NWL_i)	6.13	-	6.21
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	6.14	-	6.22
Area of specified nonwetland cover type (ACT_j)	6.15	-	6.22
Percent of area in cropland (PC)	6.16	-	6.23
Percent of cropland cover type in corn or other grain crops (PCG)	6.17	-	6.23
Percent of the area in pasture/hayland (PPH)	6.18	-	6.24
Percent of the area in idle land (PIL)	6.19	-	6.24
Distribution of idle cover (DIC)	6.20	-	6.25
Distance to a wetland ≥0.4 ha (DW)	-	6.1	6.14

LITERATURE CITED

Higgins, K.F. 1977. Duck nesting in intensively farmed areas of North Dakota. J. Wildl. Manage. 41(2):232-242.

Stewart, R.E., and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Bur. Sport Fish. Wildl. Resour. Publ. 92. 57 pp.

_____________. 1973. Ecological distribution of breeding waterfowl populations in North Dakota. J. Wildl. Manage. 37(1):39-50.

7. ISLAND CONSTRUCTION
a. Nesting islands (waterfowl)

MANAGEMENT ACTION INFORMATION

Purpose

Construction of nesting islands for waterfowl is intended to provide additional nesting habitat that is free from predation. Island habitat may be particularly important in areas where upland nesting habitat is limiting (Giroux 1981).

Effects of Management Action

Island construction increases the overall area of nesting habitat while decreasing the area of the wetlands in which islands are constructed. Island construction can significantly influence production of certain waterfowl species. Jones (1975) lists the following as characteristics of island habitat that contribute to increased waterfowl production: (1) increased security and nesting success due to a reduction in predation and human disturbance; (2) an increase in the shoreline to surface area ratio within a wetland which increases the amount of pair habitat; and (3) security, loafing sites, and feeding areas during the brood-rearing period. The increased survival and production of waterfowl on islands leads to a rapid increase in populations due to subsequent homing of waterfowl to the island habitat. In order to achieve increased production, islands should be located sufficiently far from mainland (at least 30 m), have a channel depth of 0.5 to 0.6 m, and have a long, narrow shape with surface area ≥0.02 ha (Jones 1975). Giroux (1981) recommended that islands be at least 170 m from the mainland, with water depth around the islands of at least 70 cm.

Nest success of mallards (Anas platyrhynchos) on small constructed islands in a North Dakota study was 63%, compared to 29% success in upland habitat (Johnson et al. 1978). The average island (average size of 0.003 ha) produced an equivalent number of mallard ducklings as did 21.2 ha of upland habitat. Density of waterfowl nests was inversely correlated with island size on constructed islands in Alberta (Giroux 1981).

Lokemoen (1984) evaluated the effects of several management actions intended to increase waterfowl production and found that constructed islands (≥0.04 ha) yielded the greatest number of fledged young of 10 management actions considered. The islands were planted to an introduced grass-legume cover or snowberry (Symphoricarpos occidentalis) and Wood's rose (Rosa woodsii) roots.

Maintenance and Management

Islands may be created by a variety of techniques. During wetland or reservoir construction, islands can be built by isolating the tips of peninsulas or by piling earth from a moat (Giroux 1981). Islands in existing wetland basins can be created during dry periods (Johnson et al. 1978), or by using land-based equipment to dig a moat and pile earth within the wetland (Jones 1975).

The amount of labor, materials, and maintenance involved in island construction may vary considerably with island size. Small islands ranging in size from 0.0002 to 0.01 ha were constructed in dry wetland basins in North Dakota in only 1 to 2 hours at an average cost of $50.00 (Johnson et al. 1978). Construction involved a D-7 Caterpillar tractor and dump truck. The islands were not seeded, but were vegetated within 1 year after construction. Giroux (1981) recommended that islands be rectangular due to the greater perimeter to area ratio of this shape compared to elliptical, circular, or square islands. Islands created by earth scraping prior to flooding of new reservoirs in Alberta cost approximately $2,300/0.1-ha island, at an average cost of $1.50/m^3 of earth moved (Giroux 1981). Jones (1975) reported that costs of islands in new reservoirs ranged from no additional expense to $150 for larger islands (approximately 0.2 ha), and that smaller islands (approximately 0.02 ha) could be constructed in only a few hours with earth moving equipment.

Construction of larger islands involves the use of costly, heavy machinery (Lokemoen 1984). The initial cost of constructing 0.4-ha islands in dry impoundments was estimated at $9,845 (Lokemoen 1984). Itemized costs included in this estimate are presented in Table 7.1. The life of the management action was estimated at 20 years, with an annual maintenance cost of $93.50 expended on predator control.

Costs of constructing small islands in constructed or restored wetlands in North Dakota was estimated as part of the Garrison Diversion Unit study. These estimates indicated that islands 6.1 m in diameter and 1.8 m high (0.9 m above water line and 0.9 m below water) cost $1,117.44 for each 0.003-ha island, with an estimated annual maintenance cost equal to 2% of the initial cost (i.e., $22.35) (Table 7.2). More than half of the initial cost of the estimates in Table 7.2 resulted from the high cost of riprap for each island, which may not be necessary for a given small island.

It is evident from the information presented above that costs for island construction vary considerably, depending on island size, availability of material and equipment, need for riprap, and other factors. Due to this high degree of variability, managers interested in island construction as a management action are advised to develop site-specific cost estimates.

16)

Table 7.1. Itemized costs of constructing 0.4-ha islands in the Dakota pothole region (from Lokemoen 1984).

Activities	Cost
Development activities	
Earthmover[a]	$7,900.00
Rock riprap[b]	690.00
Topsoil[c]	1,005.00
Surveying, etc.	250.00
Total development cost/0.4 ha	$9,845.00
Maintenance activities	
Trapping predators (8 hr)	$ 52.32
Transportaton (50 mi)	16.50
Equipment (boat, traps, etc.)	25.00
Total annual cost/0.4 ha	$ 93.50

[a] An island 7 feet high with a 5:1 side slope would entail 15,714 cubic yards. A large bulldozer moves about 200 yards per hour, or about 79 hours for total.

[b] Estimated 185 cubic yards (6 feet wide, 1 foot deep) of rock carried by a 4-cubic yard truck for riprap.

[c] Estimated a 4-inch covering of topsoil with buckbrush and rose roots on one-half of island.

Table 7.2. Itemized costs of constructing 0.003-ha islands in North Dakota.[a]

Item	Amount	Unit cost	Item cost
Fill material	78 yd^3	\$0.85/yd^3	\$ 66.30
Shaping	2 hr	\$32/hr	64.00
Transport of fill	78 yd^3	\$32/hr	416.00
Riprap	257 ft^2	\$20/yd^2	571.11
		Total	\$1,117.44
Annual maintenance (2% of construction costs)			\$22.35

[a] Estimates from: Olson, R.W., and R.C. Solomon. 1982. Garrison Diversion Unit, unpublished file data. U.S. Fish and Wildlife Service, Fort Collins, CO. n.p.

HABITAT MANAGEMENT MODEL

Model Applicability

Cover types. Island construction can presumably occur in any wetland basin. In practice, however, islands will be constructed in basins with a relatively high degree of water permanence in order to achieve the greatest waterfowl production due to predator protection gained by having a water barrier to travel by mammalian predators. Most islands will likely be constructed in wetlands that are permanently or semipermanently flooded. Islands constructed in dry impoundments (e.g., during wetland construction or restoration) will be most cost-effective.

Minimum management area. Construction of very small islands has been successful in increasing waterfowl productivity in some areas (Jones 1975; Johnson et al. 1978). Therefore, no minimum size for island construction is specified in this model. Actual island size is a site-specific parameter.

Model Description

Overview. Island construction affects a number of habitat variables (Table 7.3). Initially, the major influence of island construction is to increase the area of a cover type (typically a tame grassland or shrubland type), while decreasing the area of wetlands of a given wetland class. In the event that island construction is occurring in newly constructed wetlands, the

Table 7.3 Habitat variables potentially affected by construction of islands.

Habitat variable (acronym)	Direction of change[a]	
	Increase	Decrease
Area of wetlands of a specified wetland class (AW_i)		X
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)		X
Area of specified nonwetland cover type (ACT_j)	X	X
Percent of area in cropland (PC)		X
Percent of cropland cover type in corn or other grain crops (PCG)	X	X
Percent of area in pasture/hayland (PPH)		X
Percent of area in idle land (PIL)		X
Distribution of idle cover (DIC)		X
Distance to a wetland ≥0.4 ha from a specified nonwetland cover type (DW_j)		X

[a] The direction of change refers to the most likely difference in the quantity of a variable as a result of constructing islands. Variables for which both a positive and negative change are indicated are the results of changes in different cover types.

area of one upland cover type (i.e., islands) is increased at the expense of the cover type in which the wetland and island(s) are constructed (i.e., the host cover type). Habitat variables that describe the structure of vegetation on the constructed island will also change over time, though not in response to the number or area of islands constructed. Average annual values for such variables must be estimated in order to determine Average Annual Habitat Units for a given species. This can be done by estimating values for each variable at selected target years over the life of the management action. Lokemoen (1984) assigned a life expectancy of 20 years to 0.4-ha constructed islands, and 50 years to small rock islands. In order to determine impacts of island construction on the wildlife species identified in the Introduction, an average annual value must be estimated for the average visual obstruction measurement over the life of the island.

The influence of island construction on each of the variables listed in Table 7.3 is discussed below. Several of the impacts are straightfoward and are discussed only briefly, while several require a number of assumptions and are discussed in more detail.

Area of wetlands of a specified wetland class (AW_i). Island construction decreases the amount of surface area of water present in existing, restored, or constructed wetlands. As used here, wetland area equals the area of surface water contained within the wetland boundaries and does not include the area of any islands contained within the basin. Functionally, this relationship is expressed as a simple subtraction, as in Equation 7.1.

$$AW_i = AW_{iB} - AI_i \tag{7.1}$$

where AW_i = the area of wetlands of class i present following a management action

AW_{iB} = the area of wetlands of class i prior to management

AI_i = the area of all islands constructed in wetlands of class i

Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i). The influence of island construction on this variable is functionally identical to that expressed in Equation 7.1, with the exception that the variable applies only to wetlands ≥0.4 ha. The relationship is expressed in Equation 7.2.

173

$$AWL_i = AWL_{iB} - AIL_i \qquad (7.2)$$

where AWL_i = the area of wetlands ≥0.4 ha of class i present following a management action

AWL_{iB} = the area of wetlands ≥0.4 ha of class i prior to management

AIL_i = the area of all islands constructed in wetlands ≥0.4 ha of class i

Area of specified nonwetland cover type (ACT_j). Island construction may either increase of decrease the area of a given nonwetland cover type. When islands are constructed as part of wetland restoration or construction, the newly created cover types replace an existing cover type. If the wetland area refers only to the surface area of water, the area of the host cover type must also be decremented by the area of islands. In many cases, wetland area includes both the area with water and the area of islands. In such instances, users should be cautious about the possibility of "double-counting" the area of islands.

Construction of islands also increases the area of specified nonwetland cover types, depending on the management of given islands. For example, islands planted to introduced cool-season grasses will increase the area in tame grassland, whereas those planted to shrubs will increase the area of shrubland. Due to the increased production of waterfowl on island habitats compared to upland habitats of the same cover type, it may be desirable to keep separate upland and island areas of the same cover type (e.g., tame grassland/upland and tame grassland/island). The relationships between island construction and the area of specified nonwetland cover types is expressed in Equation 7.3.

$$ACT_j = ACT_{jB} - AI_j + AIN_j \qquad (7.3)$$

where ACT_j = the area of a specified nonwetland cover type j following a management action

ACT_{jB} = the area of a specified nonwetland cover type j prior to management

AI_j = the area of islands constructed in what was formerly cover type j

AIN_j = the area of islands that are planted or naturally succeed to cover type j

Percent of area in cropland (PC). Island construction influences the percent of an area in cropland only if islands are constructed in what was formerly cropland (i.e., cropland is the host cover type). In such cases, island construction will decrease the proportion of an area in cropland, as expressed in Equation 7.4.

$$PC = \left[\frac{ACT_{3B} - AI_3}{\text{Total study area}}\right] \times 100 \qquad (7.4)$$

where PC = the percent of an area in cropland following a management action

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

AI_3 = the area of islands constructed in what was formerly cropland (nonwetland cover type 3)

Percent of cropland in corn or other grain crops (PCG). Island construction in cropland that currently produces corn or other grain crops will decrease the relative amount of the cropland area in these crops. Alternatively, island construction that replaces crops other than corn or other grains will increase the relative proportion of the cropland area in corn or grains. These relationships are expressed in Equation 7.5.

$$PCG = \left[\frac{ACG_B - AICG}{ACT_{3B} - AI_3}\right] \times 100 \qquad (7.5)$$

where PCG = the percent of the cropland cover type in corn or other grain crops following a management action

ACG_B = the area of cropland in corn or other grain crops prior to management

AICG = the area of islands constructed in cropland formerly producing corn and other grain crops

ACT_{3B} = the area of cropland (nonwetland cover type 3) prior to management

AI_3 = the area of islands constructed in what was formerly cropland

Percent of area in pasture/hayland (PPH). This variable is an estimate of the proportion of an area supporting the land uses of grazing or mowing. Pasture/hayland was not included as a cover type in the introduction. Rather, pasture/hayland results from certain land uses on tame or native grasslands. The relationship between this variable and island construction is functionally similar to the percent of area in cropland, discussed previously (Equation 7.4). The relationship is expressed in Equation 7.6.

$$PPH = \left[\frac{APH_B - AIPH}{\text{Total study area}}\right] \times 100 \qquad (7.6)$$

where PPH = percent of an area in pasture/hayland following a management action

APH_B = the area of pasture/hayland prior to management

$AIPH$ = the area of islands constructed in cover types used as pasture or hayland

Percent of area in idle land (PIL). Idle land is defined as any land that is not planted to crops, hayed, or grazed by domestic livestock. It is a sum of a specified habitat condition across a number of cover types, including tame grassland, native grassland, shrubland, or woodland. The variable is used to evaluate habitat suitability for the gray partridge, which is not expected to use island habitats regardless of cover conditions on the islands. Therefore, island construction can only decrease the level of this variable in situations where islands are constructed in cover types that were idle prior to island construction. This relationship is expressed in Equation 7.7.

$$PIL = \left[\frac{AIL_B - AIIL}{\text{Total study area}}\right] \times 100 \qquad (7.7)$$

where PIL = the percent of an area in idle land following a management action

AIL_B = the area of idle land prior to management

AIIL = the total area of all islands constructed in cover types that are not grazed, hayed, or in crop production

Most island construction will likely occur in cover types that are not classified as idle. Island construction in existing wetlands will not influence the percent of an area in idle land. Similarly, this variable will not change as the result of islands constructed in cropland or cover types used for pasture or hayland. If these situations represent the only cover types and land uses in which islands can be constructed in a given study, then Equation 7.7 may be ignored.

Distribution of idle cover (DIC). This variable equals the number of square 4-ha grids on a 2.59-km² sample area that contain or border idle habitat, defined as upland habitats that are not grazed or hayed and do not support crops. Island construction may potentially reduce this variable, but only if all the idle habitat in a given 4-ha block is eliminated. This functional relationship is expressed in Equation 7.8.

$$DIC = NGIL_B - NGIC \qquad (7.8)$$

where DIC = distribution of idle cover, i.e., the number of square 4-ha grid cells per 2.59 km² that contain or border idle cover following a management action

$NGIL_B$ = the number of 4-ha grid cells per 2.59 km² that contain or border idle cover prior to management

NGIC = the number of grid cells in which idle cover is eliminated as a result of island construction

It is unlikely that island construction will ever change the distribution of idle cover, for two reasons. First, islands will be constructed either in existing, constructed, or restored wetlands. In the latter two situations, the activity is most likely to occur in cover types that do not meet the definition of idle cover (i.e., in cropland, pasture, or hayland). Second, constructed islands will be relatively small, making it even more unlikely that all of the idle cover in a 4-ha cell will be eliminated due to island construction. If either of the above situations is true for a given application of this model, then island construction will have no impact on the distribution of idle cover and Equation 7.8 may be ignored.

177

Distance to a wetland ≥0.4 ha from a specified nonwetland cover type (DW_j). Construction of islands will typically occur in the more permanent and larger wetlands. It is assumed in this model that islands will only be constructed in wetlands ≥0.4 ha, resulting in new potential nesting habitat in close proximity to a wetland ≥0.4 ha. The cover type created by island construction will likely be either native grassland or shrubland. The new area of such cover types may be treated as separate from upland areas of similar vegetation, or combined with similar upland cover types. In the former case, the average distance from a wetland ≥0.4 ha must be calculated only from islands. In the latter case, the island to wetland distance must be averaged with the upland (of the same cover type) to wetland distance. Both of these approaches are described below.

A distance estimate from island cover types to wetlands ≥ 0.4 ha can be made via a map exercise, i.e., by selecting random points and measuring from those points, or by deriving an average distance based on an assumption that islands will be circular in shape. The average distance from random points on an island to the edge of the island and, therefore, to a wetland ≥0.4 ha, can be estimated by Equation 7.9. Equation 7.9 calculates the radius that results in exactly one-half of the area, which defines the average distance from random points in a circle to the circle's edge.

$$DW_j = \sqrt{A/2\pi} \qquad (7.9)$$

where DW_j = the average distance to a wetland ≥0.4 ha from cover type j [where j will typically be either native grassland (j=2) or shrubland (j=4)] following a management action

A = the area of the island under consideration (the island is assumed to be circular)

If the area of a specified cover type occurring on islands is to be combined with upland areas of the same cover type, the average distance is determined by weighting the distances from uplands and islands by the area in uplands and islands, as in Equation 7.10.

$$DW_j = \frac{(ACT_{j1} \times DW_{j1}) + (ACT_{j2} \times DW_{j2})}{ACT_{j1} + ACT_{j2}} \qquad (7.10)$$

where DW_j = the average distance to a wetland ≥0.4 ha from cover type j

ACT_{j1} = the area of cover type j occurring in upland situations

DW_{j1} = the average distance to a wetland ≥0.4 ha from cover type j occurring in upland situations

ACT_{j2} = the area of cover type j occurring in island situations

DW_{j2} = the average distance to a wetland ≥0.4 ha from cover type j occurring in island situations

Model Relationships

The presumed relationships between wetland construction and a number of habitat variables were described in the preceding section. Table 7.4 presents a summary of the variables discussed in the model and a reference to the equation(s) which describes each relationship.

Application of the Model

This model can be used to evaluate the influence of island construction on a number of habitat variables. The model can be used in management gaming or in the evaluation of mitigation or management plans. Most of the functional relationships are straightforward, although the model user must supply site-specific information before using the model. The information that must be provided by the user is as follows.

1. Baseline conditions for all habitat variables.
2. The cover types to be established either naturally or through management on constructed islands.
3. The area of islands constructed in cover types used for grazing or mowing.
4. The area of islands constructed in idle cover types, i.e., cover types that are not grazed, mowed, or in crop production.
5. The number of 4-ha grid cells in which all idle cover is eliminated as a result of island construction.

Table 7.4. A summary of the habitat variables potentially affected by construction of islands.

Variable (acronym)	Equation	Page
Area of wetlands of a specified wetland class (AW_i)	7.1	7.6
Area of wetlands ≥0.4 ha of a specified wetland class (AWL_i)	7.2	7.7
Area of specified nonwetland cover type (ACT_j)	7.3	7.7
Percent of area in cropland (PC)	7.4	7.8
Percent of cropland cover type in corn or other grain crops (PCG)	7.5	7.8
Percent of area in pasture/hayland (PPH)	7.6	7.9
Percent of area in idle land (PIL)	7.7	7.9
Distribution of idle cover (DIC)	7.8	7.10
Distance to a wetland ≥0.4 ha from a specified nonwetland cover type (DW_j)	7.9,7.10	7.11

LITERATURE CITED

Giroux, J.F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. J. Wildl. Manage. 45(3):669-679.

Johnson, R.F., Jr., R.O. Woodward, and L.M. Kirsch. 1978. Waterfowl nesting on small man-made islands in prairie wetlands. Wildl. Soc. Bull. 6(4):240-243.

Jones, J.D. 1975. Waterfowl nesting island development. U.S. Bur. Land Manage. Tech. Note 260. 17 pp.

Lokemoen, J.T. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

GPO 854-825

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-822A, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.